HARMSWORTH POPULAR SCIENCE

EDITED BY ARTHUR MEE

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THE SPIRIT OF SCIENCE, BY EDWIN AUSTIN ABBEY, R.A.

This mural painting, in the State Capitol, Harrisburg, Pennsylvania, bears the inscription: "I am what is, what shall be, what hath been. My veil hath been disclosed by none. The fruit which I have brought forth is this—the sun is born."

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ACKED IN A TINY SEED

One of the mysteries that no man can explain is the way in which a tiny seed grows in a few months to be a beautiful flowering plant, eventually dying and providing more seed for the perpetuation of the species. Who put this beauty there? Who packed these tiny specks with the colour and wonder and fragrance of a lovely garden? At the foot of this page (from left to right) are shown the actual seeds of the scabious, the canterbury bell, the sweet pea, the begonia, the gaillardia, the sweet william and the antirrhinum and above them are the lovely blossoms that form out of these seeds.

BALANCING THE HEAVENS

The Mystery of Gravitation and Radiation, and the Eternal Rhythm of the Universe

THE TRACING OF THE EARTH'S ORBIT

Though in our survey of the Universe, which is the field of all science, popular and unpopular, present and to come, we included mind as well as matter or energy and ether, we are to take no further cognisance of mind here. This is not because it is less important; on the contrary. Nor is it because there is no science of mind; the rather have we paid formal homage to mind in this section, since students of the Universe have too often ignored it in their surveys, and have laid themselves open, most justly, to the charge of materialism.

Nevertheless, here we shall have no further concern with mind, for we shall even fail to understand what we confine ourselves to unless we leave the influence of mind out of the question altogether.

On this issue there can be no paltering or compromise. We see the movements of the planets and the moon, and the rotation of the sun; the daily rotation of our own planet is no less certainly to be inferred. On further inquiry we discover that there are shooting stars and comets which move, and that the "fixed stars," as our fathers called them, are all in motion, fast or slow, some towards us, some away from us, others in all other directions. These movements are in part so little comprehensible that they may appear chaotic and ungoverned. On the other hand some of them, such as the movements of the planets, are regular and systematic, as if under intelligent guidance. Are we, then, to say that things are largely a higgledy-piggledy, but that here and there the working of a rational intelligence can be observed? Does mind come into our Universe in this sense?

Modern science denies both of these propositions with equal solemnity and conviction. The apparent chaos of starry movement is only apparent, not real. It is the expression of order hitherto undiscerned. The apparently purposeful and deliberate movement of other heavenly bodies is only apparently so. It is the expression of the uniform working of mechanical laws. And, beyond both of these denials, science makes the positive affirmation that, whatever else be dubious, this stands: order is everywhere or nowhere, mind is everywhere or nowhere, God is everywhere or nowhere.

The last thing that science can deny is the existence of mind behind all things, but science makes its beginning, and its primary and fundamental claim, when it affirms that the world of sense and apprehension is orderly and entire, not unsuited to represent to us a Mind which is orderly and entire; and that to affirm the action of the hand of God or His agents at any particular spot is, by implication, to deny it elsewhere. This may be dared by some, in the name of religion, but this science cannot dare.

These are fundamental philosophic considerations which we need to have in our minds when we approach the problem of explaining the movements of the heavenly bodies. Nor can we better realise the difference that these ideas make to us today than by recalling the theory of the heavens which was maintained by, for instance, the great astronomer Kepler, to whose researches we owe it that Newton was able to formulate the law of universal gravitation.

Kepler knew nothing of the movements of the "fixed stars" (including, as we now realise, our own sun) through space. To him they were indeed fixed; and with them he contrasted, as so many have done before and since his day, the movements of those bodies which the ancients called the planets, or wanderers. Kepler was born late enough in time to accept the teaching of Copernicus, and include our earth in the category of planets. He was the supreme student of the

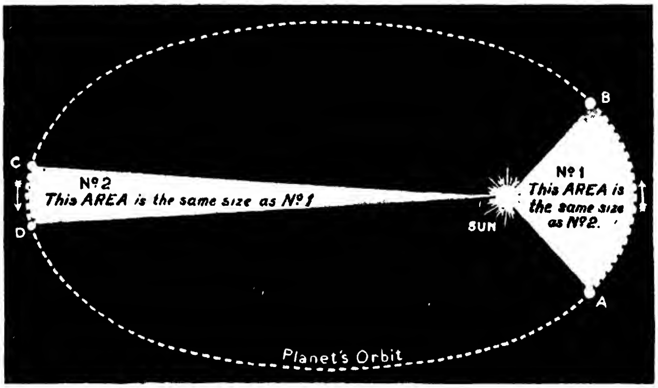
motion of the planets, the order and uniformity of which he discovered. But his philosophic ideas were other than ours, and the views which we have rejected were just and necessary to him.

It is recorded of him that, being asked by his wife what he had been doing all the hours of "star-gazing," he replied that he had been "thinking the thoughts of God after Him." A noble reply, yet, as perchance we shall duly see, not noble enough. His theory of the Universe involved the belief that the fixed stars were where God had put them; and that the planets, the order of whose movement he had discovered, were impelled and maintained in their orbits by heavenly beings, the agents of God, whose "thoughts" their movement expressed.

It is the one decisive, incomparable step for the human mind to deny Kepler's explanation; to exclude the activity of any form of will or intention or caprice from our explanation of any part or fact of the Universe, partly on the ground that these explanations do not explain, partly because, as we are about to see, other explanations are possible; and, above all, because to confine Deity to any part or fact of things is to exclude Him from the rest. Such are the reasons why the substitution of Newton's law of gravitation for Kepler's theory of the motion of the planets is typical and representative, on a great and illustrious scale, of the age-long processes, everywhere illustrated, whereby superstition, with its small idea of God, yields to science, whose idea of Him can never be less than infinite.

Men whose idea of the Universe was as mean as Galileo's was great were offended at his blasphemy in descrying spots upon the majestic face of the sun. Men of a similar type were entirely indisposed to consider any additions to the number of the sun's family, because the perfect number is seven, and such must be the number of the planets. Yet again, just as the sun must be spotless, and the number of his family the perfect number, so their movement round him (if, indeed, we are to admit that the planets, including the earth, do move round him, and not all things round the earth) must at least be itself perfect. Now, there is only one perfect figure on this theory of perfection, and that is the circle. Therefore, the planets, perfect in number, must move round the spotless face of their perfect sun, in the perfect figure of circles, and with perfectly constant speed.

It is, perhaps, easy to ridicule such assumptions to-day, especially since most of those who ridicule would then have been found among the number of the ridiculous. We must remember that, with all this folly and idleness of mind, there was in some cases, at any rate, a sincere desire to glorify God, and that the indignation of such men against those who controverted their evidence of perfection was in part sincere and admirable in spirit.



THE CHANGING PACE OF THE EARTH ROUND ITS ORBIT

This diagram illustrates one of Kepler's laws. A line drawn from the sun to the earth takes the same time to pass over the area No. 1 as it does to pass over the equal area No. 2, the motion of the earth being swifter between A and B than between C and D.

Just so is the present indignation of many religious people, now quite content to accept Kepler and Newton, against the work of modern men who seek, say in the study of heredity, to think the thoughts of God after Him, even though they appear, in dull eyes—perhaps their own—to sap the foundations of moral responsibility. Let us learn for the present from the past.

Now, if the planets move in circles round the sun, at constant speeds, there is no more to be said. The thing is so, because it is so; and has no meaning. Nothing deeper, nothing wider, is involved. But we may find a deeper and wider perfection even than that of the perfect figure, if we look into the facts, and discover that the figures described by the planets are not perfect at all—in this very imperfect sense.

John Kepler was born in 1571, a delicate baby, belonging, like Newton himself, to the number of those very weakly children whom certain later mathematicians would

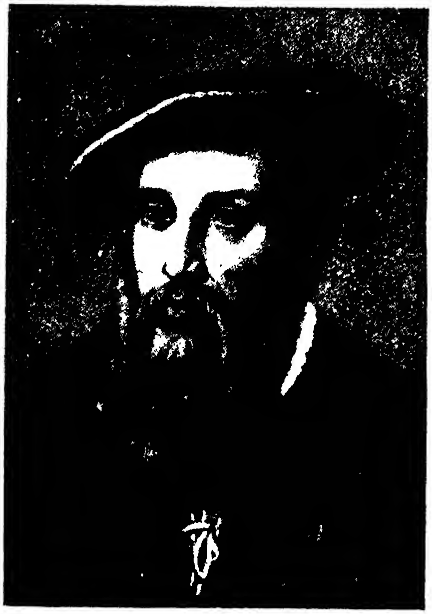
now gladly see allowed to die. He was nearly forty when, after long years of that labour for which his wife's patience seems to have been less adequate than his own, he announced, on the strength of his study of Mars, that the orbit of a planet is not a circle but an ellipse. At this time, and ten years later, he also announced two other laws, making, with the first, Kepler's three laws of planetary motion, upon which, as the basis for the law of gravitation, soon to be discovered by Newton, modern astronomy may justly be said to rest.

These three laws are, first, that the planets move, not in circles, with the sun at the centre, but in ellipses, with the sun at one focus (of the two which an ellipse possesses); second, that, as a planet moves round the sun, the line from sun to planet passes over equal areas in equal times, which means that the planet must move more rapidly when nearer the sun than when further away; and third, that there is a constant proportion between the time that a planet takes to go round the sun and its distance from the sun.

These are the three great laws of planetary motion, of which we may say, with equal truth, that the law of gravitation is inferred from them, or that they can be deduced from the law of gravitation. It is Newton's supreme fame that, pondering on these things, he replaced Kepler's celestial spirits, which urged and steered the planets in their orderly course, by a force of gravitation, directed to or from the sun, and acting along the ever-moving line between the planets and the sun. This force it is that controls the planets, as it controls the moon; and the mind of Newton was great, not merely because of his mighty mathematical genius which enabled him to infer the law from the facts, but from its possession of a quality almost opposite, a quality almost or wholly poetic, whereby small things and great are seen as one. Newton could guess that an apple falls to the earth, and a moon or meteors ever seek to fall to the earth, and earth and planets and comets to the sun, and stars to one another, and all things to all things. His law, thus local in its original application, far transcends the solar system, of which it is the key. It asserts that:

"Every particle of matter in the Universe attracts every other particle with a force in the direction of a straight line joining the two, whose magnitude is proportional to the product of the masses, and inversely proportional to the square of the distance between them."

We may briefly note the various clauses of this law before we consider its meaning. It shows us that gravitation is not the pull of the earth for the apple, or the sun for the earth, any more than it is the pull to the apple for the earth, or the earth for the sun. Big and little, all alike attract each other. The result, which is of mutual and common origin, will show itself in the motion of *both*, but this motion will amount to more where there is less to more—that is to say, in the case of the less massive body. The earth rises to the apple, but the movement is, of course, inconceivably infinitesimal, and all we notice is that the apple drops to the earth.



JOHN KEPLER, THE GERMAN ASTRONOMER

Who discovered that the earth moves round an elliptical orbit, now nearer the sun and faster, now further from it and slower.

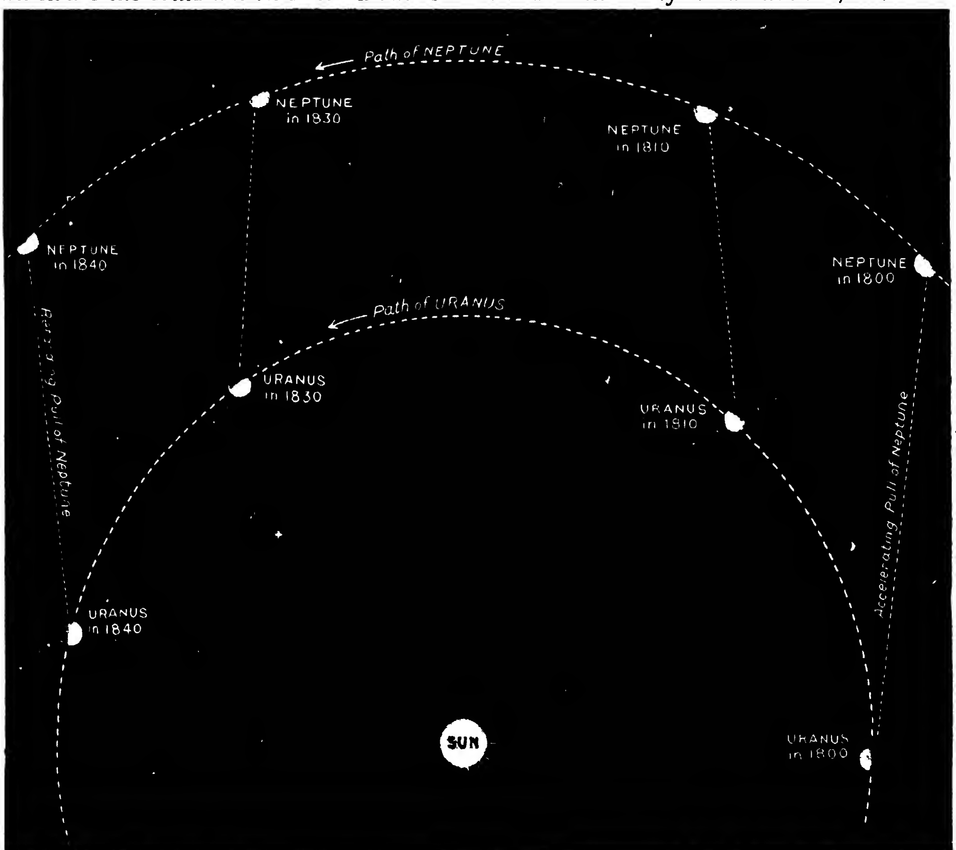
Further, the discovery that the attractive force, in the solar system, centres in the sun is superseded by the law which asserts that all matter attracts all matter. It is merely the huge mass of the sun that makes its rôle obvious. But, according to this law, the planets attract the sun, as the sun attracts them; and they attract each other. Thus, Kepler's laws or, rather, assertions of planetary motion are not strictly accurate, for they are complicated by the attraction of the planets for each other; and thus the planets do not move as if under the influence of a force solely centred in the sun.

The inaccuracy of Kepler's statements of planetary motion is, nevertheless, the best proof of their value—or, rather, it

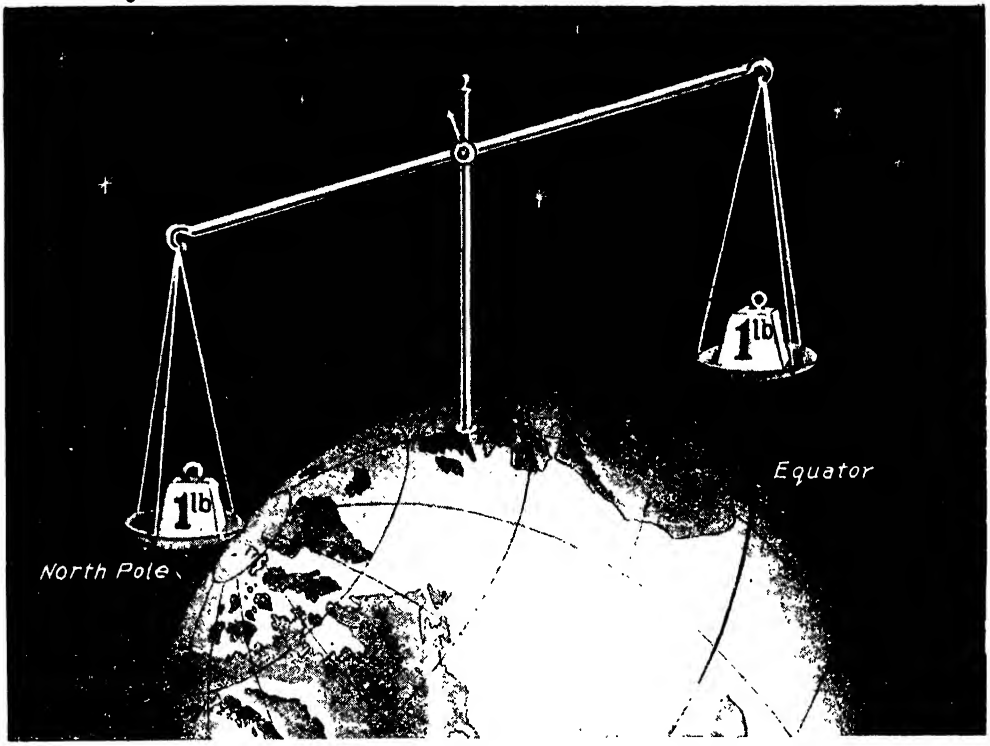
vastly enhances their value. Thus it was that the planet Uranus was found to behave somewhat otherwise than it should, according to Kepler's laws. It behaved, indeed, according to those laws, but modified somewhat, as if some other unknown celestial body were complicating its motion. If the law of gravitation simply asserted that the sun attracts the planets, it would not be the key to this case, but it asserts that all matter attracts all matter. Hence, another body, outside the sun, might be argued, to account for the abnormalities in the movement of Uranus.

Two astronomers made the necessary calculations assuming the truth of Newton's law, and they were duly rewarded by the discovery of the hitherto unknown planet Neptune, according to their predictions. This was alike one of the most notable achievements of science, and the most perfect imaginable illustration of the ideal methods of knowledge—which are the combination of the method of deduction from general to particular, with the method of observing particulars, and finding their agreement with the general law.

If we do, indeed, realise the universal character of Newton's generalisation, and how incalculably it transcends the mere notion that the sun attracts the planets, or the earth the apple, we may note next the clause which declares that the force of gravitation is exactly measurable, and is proportioned to the quantity of matter in action. Thus if we consider any two bodies, one unknown, and try to study the force of gravitation between them, we must observe the motion of the body we know; and since motion expresses force, we can infer the gravitational force at work to produce the motion we observe. But if we know the position and mass of the body we see, we are now enabled by the law of gravitation to infer the position and mass of the body we do not see, if we also



THE DISCOVERY OF A NEW PLANET BY MATHEMATICS—A REMARKABLE TRIUMPH OF THE HUMAN MIND
This drawing explains how mathematicians were able to infer the existence of a new planet, which was afterwards found in the precise place expected. It was observed that the planet Uranus travelled much faster and farther between the years 1800 and 1810 than between 1830 and 1840, and it was imagined that this was due to the pull of a then unknown planet, which accelerated the path of Uranus at the earlier date, and then retarded Uranus after it had passed a particular point in 1822. Mathematical calculations led a great astronomer to turn the telescope to a particular place in which the unknown planet was supposed to be, and there, in 1846, the planet Neptune was discovered, a thousand million miles beyond Uranus, and more than twice that distance from the earth.



WHY EVERYTHING LOSES WEIGHT AT THE EQUATOR

The earth bulges at the Equator and is flattened at the Poles, the distance from the North Pole to the centre being about 26½ miles less than the distance from the Equator to the centre. The pull of gravitation is less at the greater distance, and so a balance with one scale at the Pole and the other at the Equator would show a polar pound weigh less than a pound at the Equator.

take into account the law as to distance which concludes Newton's statement. This is the fashion in which Neptune, any possible planet outside Neptune, such as some astronomers are now suspecting, and also the dark companions of many stars, can be discovered.

Observe that Newton's law speaks not of weight but of mass. To understand the distinction is essential for all this department of science. The mass of anything is the quantity of matter in it. This is a fixed property, so to say, of the thing in question, and so remains so long as the thing is all there, and nothing is added to it. Gravitation depends upon the quantity of stuff that exerts it. But the consequence of the pull between things is that if we get in between we feel them pressing against us, and that pressure is what we call their weight. Mass is mass, and remains; mass produces the force of gravitation; and that is what we know as weight.

Thus the weight of a thing always and everywhere depends upon two factors—its mass, and the gravitational force which is being exerted upon and by it. The earth being somewhat flattened at the Poles, and bulging somewhat at the Equator, anything weighs heavier nearer the Poles, and lighter nearer the Equator, because there it is further from the earth as a whole, or from the centre of the earth.

The man who carries gold from Alaska southwards, and weighs it there, may thus be accused of having stolen some of it, for if it be weighed in a spring balance it will weigh less, being less pulled upon, though it is all there. In the same way cubes of metal, exactly similar in mass, may be made in the laboratory. Placed side by side, they will weigh the same; but if either be placed upon the other the uppermost will weigh less, for it is now further from the earth.

Thus our weight diminishes as we walk uphill, not merely because we perspire, but because, even if our mass remained the same, it would weigh less, being the subject of less gravitational pull. Yet again, to jump six feet high on the earth is a great and rare feat. To do so on the moon would be nothing, for the moon is so small that her pull is much less; but to do so on

Jupiter would be utterly impossible for us, not to say that, even if Jupiter were cool enough, nothing of the shape of our bodies could be maintained there against the tremendous force of gravitation. Any life upon so huge a planet would have to take the form of a "creeping thing." Yet once again, as Lowell has shown, digging canals on Mars would be far easier than on the earth, for the mass of material moved, though the same in the two cases, would weigh far lighter on the smaller planet.

Newton's Application to a Part of Nature of a Great Law which is Universally True

But we must first note the last clause of the law, before we consider the tremendous meaning of one all-important word which is omitted from the law, but implied therein. Newton tells us that the force of gravitation varies inversely as the square of the distance. Thus, if we increase threefold the distance between two bodies, the force of gravitation between them will be reduced to one-ninth of its former quantity; a twenty-fold increase of distance would reduce the force to one-four-hundredth, and so on. If we ask why this should be so, we do well first to ask whether it is so in any other case. At once we find that, as Newton could not know, the "law of inverse squares," as it is often called, is of general application. It could not be otherwise, if we take the case, for instance, of the intensity of light.

A simple experiment, or a diagram which we can readily follow or invent for ourselves, will show that if we double the distance of a piece of paper from a candle, the light will now cover not twice but four times the area covered before; and the intensity of the light, at twice the distance, will be one-fourth of what it was. This law of inverse squares applies to the intensity of gravitation, light, heat, sound, electrical and magnetic attraction, and we may expect it to apply in general to the distribution of all or any forces that spread themselves equally outwards in all directions.

The Great Words Everywhere and Always that Give Sublimity to Natural Laws

The one tremendous word that has been omitted from the law of gravitation, as usually stated, is *always*. This force acts continuously. Light, heat, sound, and many other manifestations of power may wax and wane. There may be intervals of darkness or silence, or, at the least, pulses in their action. Gravitation acts always, and is always constant.

In recent years we have found it hard enough to do anything whatever that will modify the course of what is called radio-activity, the constant course of which seems to defy all attempts to cajole, hasten, or mollify it. Gravitation far transcends radio-activity in this respect, as it transcends everything else we know. Its force never fails, and never varies. Innumerable experiments may be made in the attempt to influence gravitation, but they all "fail," as we say, meaning that they succeed in showing us the truth. A thing may be very hot or very cold; it may be subjected to any kind of influence we please, but before, during, or after, its gravitational power remains precisely the same, provided that its mass has not been diminished or increased. Age cannot wither it, nor custom stale its infinite persistency.

A discovery that would transcend all past achievement in the physical realm would be that which enabled us to control gravitation, as we control the lighting of our rooms by touching a switch. Scarcely less effective would be the discovery of some obstacle that gravitation could not penetrate.

The Force that Binds All Things Together Every Moment and Knows No Obstacles

But gravitation ignores all obstacles, and acts exactly as if they were not there, like a great man going his course through his critics. We may measure the gravitational force exerted between two bodies, and then try to modify it by the interposition of obstacles, by the formation of a vacuum between them, and so forth. It makes no difference. Let us change the mass of either body ever so slightly, or alter the distance between them ever so slightly, and the result is certain and constant; but nothing else that we can devise or imagine affects their mutual gravitation in the slightest degree. Change of temperature or pressure, or physical condition, or chemical combination or separation, or magnetism, or what you will, does not influence this force. So much further, then, are we from being able to abolish gravitation altogether, even for a moment, or to delay its action by the most infinitesimal period of time.

This last clause is noteworthy; and the assertion that we cannot delay the action of gravitation is not to be taken as meaning either that gravitation takes time, or that, if it does, that time can never be modified. Obviously, the question is of tremendous importance, for if gravitational force required any time to travel, even though

its speed were that of light, the consequences in the tremendous distances of starry space would be stupendous. So far as can be ascertained at present, gravitation has no speed, for it is instantaneous. Distance duly and rigorously affects its force, according to the law we have noted, but otherwise distance appears not to exist for it.

The greatest speed we know is that of light and radiant heat and electric waves in general, which travel through the ether at a rate of more than 186,000 miles in a single second of time. Fast though this be, it involves thousands of years when we contemplate the distances of space. Everything would be different if gravitation required even such an unthinkable speed as this, but, so far as we can discover, it has no speed at all. It is simply there.

Men of science never cease to wonder at the strange misconceptions of science which are entertained by the most illustrious men whose business is not science. As it is the custom of men of science to bungle horribly outside their own domain, there need be no undue contempt on either side. But the law of gravitation has constantly proved a stumbling-block. Tennyson was a great poet, a great thinker, and a life-long student of science, of whom Huxley declared that no poet since Lucretius had so realised the meaning of the message of science to the world. Yet Tennyson asked Huxley how the ascent of the sap in a plant could be reconciled with the law of gravitation.

Kingsley was a great writer and a noble thinker, but he was once involved in a controversy with men of science, in which he declared that when he held an apple out in the palm of his hand he "defied" the law of gravitation. The man of science cannot but gasp at what seem to him to be such incomprehensible misunderstandings, but probably the fault is his, that he habitually expresses himself so badly. The rise of the sap in a plant, or of a bird or a ball or an aeroplane in the air, or the blood coursing upwards through one's neck to one's brain, or the maintenance of the apple in one's hand—neither these nor any other fact that can be named is either incompatible with gravitation or "defies" it.

The law asserts the existence of a constant force acting between things. But the world displays many forces, of which this is only one. The bird, the ball, the flying-machine, set one force or another to act in the opposite direction to that in which gravitation acts, and the results

THE OUTWARD PRESSURE OF THE SUN'S HEAT

When a comet is far from the sun it appears a shapeless patch of light, but as it approaches it develops a streaming tail of light that looks as if it were blown away from the sun. This effect is supposed to be produced by the repelling power of the sun's radiated heat.

are in due accordance with the proportion and direction of the forces involved in each case—of which gravitation, the sleepless and unweary, is but one.

If you hold an apple out in your hand, and decree that it shall have no weight, then verily you defy gravitation. If the gull which some cad, visiting Margate, has shot and killed, does not drop, then, indeed, the law of gravitation is defied. If an aeroplane could soar and remain aloft in a vacuum, and without spending any energy, then, indeed, the law would be no law. But if anyone will show us how to turn the gravitation on and off, as one "turns the light on," certainly the world will be a new place henceforth, though whether habitable by the inventor or anyone else we may question.

How Concentrated Forces Quite Small in Themselves Can Counteract Gravitation

Not merely is gravitation only one of the forces of the Universe, but it is by no means a very powerful force, according to our usual estimates. Hold a closed envelope, address upwards, and the gum will suffice to counteract the force of gravitation between the flap and the earth. Molecular forces, such as cohesion and capillarity, may readily suffice to cause the ascent of the sap in the plant, against the pull of the earth, and without in any way justifying Tennyson's doubt.

The heart of a toddling child will send a stream of blood vertically upwards against the pull of the whole earth, by means of the more than counteracting force of its delicate young walls; even a new-born infant, lying on its back, can exude a bubble of saliva from its mouth against the earth's pull: and only when we are very ill or tired can we no longer raise our eyelids.

The Unfailing Power that Interweaves the Web of the Universe

But in all these, and in all other cases, gravitation is acting all the time, or tired eyelids would not fall; and the sufficient and constant demonstration of its constancy is to be found in the effort or force which must invariably be expended if we wish to accomplish or arrest any movement against the line of its action. To assert that this force is universal and unfailing, never to be caught napping or reckoned without, is not to say, as Tennyson and Kingsley and many lesser men have unknowingly supposed, that it is the only force in the world.

If it were so, how should the earth or any other planet be maintained in its orbit? According to Newton's law, there is an attractive force between sun and planets; Tennyson might just as well have asked how the law of gravitation is compatible with the fact that the earth does not rush headlong to the sun, but travels round it from age to age. The answer is that the force of gravitation is only one of the forces involved. Our ancestors used to speak of "centrifugal," or centre-fleeing, and "centripetal," or centre-seeking force. They said that the earth keeps in its course because the centre-seeking and the centre-fleeing forces balance. The terms are poor, and the explanation inadequate.

Newton taught us to see a force-attracting sun and planet (though the planet does not move in a circle, and there is thus no centre to seek); and he also taught us, in virtue of his "first law of motion," that the planet, like every other moving body, tends to move "straight ahead" at a constant speed for ever. This is not a centre-fleeing or "centrifugal" force, but the expression of the law of inertia, which says that moving things move blindly on if nothing prevents them.

Why the Sun, Moon, and Stars Do Not Rush Together in One Mass

Thus, if the force of gravitation were arrested, a planet would fly from its orbit, not away from the sun, as the old term "centrifugal" would suggest, but in the line of its motion at the moment when gravitation ceased—"off at a tangent," as we say, like the drops from a twisted umbrella or a stone from a sling.

On the other hand, if something arrested the motion which is in the planet, so that it stood still, the force of gravitation would then be without anything to balance, and the planet would fly headlong to the sun. To suggest that gravitation is not acting when its action is complicated by other forces is to miss the whole point. Gravitation acts on the ascending sap or blood or aeroplane or bird as much as when they fall slowly or quickly. We think that gravitation only acts when we see the bird descend, but that is really because we don't think.

A man is acting, as his feelings tell him, when he pulls a bucket up from a well, or when he maintains it at any level, or when he lets it down. So also gravitation is always acting, be the results what they may. If it were the only force in the universe, all the matter there is would long ago have become huddled in one dense heap, moons rushing to planets, planets to

suns, and suns to one another. But there are other forces at work, such as the forces of motion which the planets possessed at their birth; and the just comprehension of the law of gravitation is Herbert Spencer's, who described it as the law which tells us how the heavens are balanced.

The recent students are showing us that, under certain conditions, the radiation-pressure from a hot body, such as the sun, may be greater than the gravitational force towards it, large though it be; and thus the sun may violently repel particles of matter in certain states—as, say, the fine gaseous tails of comets, which are well known to be produced as comets approach the sun, and to be always directed away from the sun, whether the comet is approaching or is retiring.

The Shrinking Sun Flings Forth Heat Rays which Repel Approaching Comets

Nevertheless, if this constant force, though not so insuperable as we had unthinkingly thought, be unantagonised, it may do amazing things. Its continuous action in the substance of the sun must involve a steady shrinkage, with consequently increasing density, of the solar body. But this gravitational shrinkage will involve friction, and the production of heat and light. We know little enough yet as to the source of the sun's heat, beyond being sure that it is not obtained by burning or combustion. But in our present state of knowledge it seems, or has seemed, to many, including no less an authority than Helmholtz, that the whole of the sun's incessant output of light and heat might be accounted for as the result of its gravitational shrinkage.

On this famous theory, be it noted, gravitation is the force which provides us with the light and heat whereby we live; it not only holds us to the sun, but it makes the sun worth holding to for us.

The Unanswered Question of Universal Force: What Causes Gravitation?

Further, we may now note the remarkable fact, perhaps not hitherto observed, that the sun's gravitational shrinkage produces the radiations whose pressure acts in the directly opposite way to gravitation. Thus, also, perhaps may the rhythm of the Universe be maintained.

When all this has been said, and vastly more which the mathematicians might add, and when modern astronomy has been appealed to, never in vain, for unending illustrations of the truth of Newton's law and the universality of its action, there yet remains the unanswered if not unanswerable question, with which any child may nonplus any man of science, be he another Newton: What causes gravitation?

It is a question, of course, which must be asked by every student of the subject; and many, from Newton's day onwards, have attempted to answer it. The theories of gravitation are thus very numerous and very varied, even to the famous view of Le Sage that all bodies are rained upon and so pushed on all sides, and thus, when set up opposite one another, are relatively shielded by each other, on their facing sides, and consequently "attract" one another, being, indeed, pushed towards one another. This theory carries paradox to its limits, yet for it, and many others, much can be said. Much more, however, can always be said on the other side; and gravitation remains unique and incomprehensible in our thought, though the modern students of electricity are by no means hopeless of solving the mystery some day.

At least one great discovery has been made since Newton's day, and that is expressed by our modern conception of the ether, the universal something which is the medium of gravitation. But the reader who has already surveyed that subject will realise how many steps must yet be taken before we can hope to discover the cause of this mystery of gravitation.

The Greatest Mind that Lived Alone Among the Stars

Plainly, we must first understand matter and the ether, and the exact relation between matter and the ether, before we can hope to explain the force which all particles of matter exert upon all other particles through the ether.

But such, at any rate, is the great example and type of a universal, constant law; and we may now follow, in our thousands, in our imperfect way, the superb genius of its discoverer, whose effigy in Cambridge Wordsworth described as

"The marble index of a mind for ever
Voyaging through strange seas of thought alone."

And if we wish to see how the contemplation of this law, by which the heavens are balanced, affected one of the greatest minds of our own age, we should turn to George Meredith's sonnet "Lucifer in Starlight," and read how Lucifer rose:

"And at the stars,
Which are the brain of Heaven, he looked, and sank.
Around the ancient track, marched rank on rank
The army of unalterable law."

SALT EVAPORATED FROM THE SHALLOW WATERS OF A GREAT DESERT

The salt here gathered into heaps in the Colorado Desert, California, has been evaporated from the intensely salty shallow waters, and is stacked ready to be taken away for greater purification.

METALS THAT SEEK A MATE

How the Alkaline Metals, by Clinging to Others and Changing Partners, Build Up Life in Plants and Give Stability to Animal Frames

FROM SEA-SHELL TO MILAN CATHEDRAL

We have considered the properties and uses of some of the chief metals, such as iron, aluminium, gold, silver, and mercury, and we now come to describe another important group of metals, known as the *alkali* metals, which have played an important part in the development of applied chemistry, and are the basis of a huge industry in which Great Britain leads the world.

The alkali metals are so named because their compounds have the property of neutralising acids, and forming with them other combinations known as salts.

The alkali metals are sodium, potassium, lithium, cæsium, rubidium, calcium, magnesium, barium, strontium, and beryllium. The most common and most interesting of the alkalis are the well-known metals sodium, potassium, and calcium.

These metals were discovered and isolated by Sir Humphry Davy a little more than a hundred years ago. In Nature they are never found pure, but always in combination with other elements. Regarded as metals, they are very poor specimens of their class: they have little lustre; they have hardly any tenacity or ductility; they are lighter than water, and they are so soft that they can be kneaded with the fingers. They certainly cannot be used for purposes for which other metals are used: we cannot make knives or forks of them, or even bracelets and ornaments.

Further, they have such a craving for oxygen and hydrogen that they clutch both whenever they get a chance, and become transformed into compounds unlike their real pure selves. So fond are they of hydrogen and oxygen that if a piece of potassium be put upon a basin of water it will rush about over the surface of the water, tearing the particles of water in pieces to get these elements for itself, and by the very force of its efforts will create enough heat to set the hydrogen on fire—enough heat, that is to say, to enable part of the liberated hydrogen to join the oxygen of the air and form water again. Sodium is not quite so ardent, and will not set the hydrogen on fire unless the water be heated, but it, too, has a great craving for hydrogen and oxygen.

Sodium is one of the most universally distributed, perhaps the most generally distributed, of the elements, but it is never found free, always in combination, chiefly as common salt. If it occurred free it would be a very active element indeed, but its very activity must have given it a very brief unwedded life. It is best known in its combination with the gas called chlorine, when it forms the substance known as common salt. There are calculated to be at least 36,000 million million tons of salt in the sea, or about fourteen and a half times the bulk of the entire continent of Europe above sea-level. If this amount of salt could be spread equally over the bottom of the sea it would cover it with a deposit of strata about one hundred and seventy feet deep, or if spread over the surface of the earth it would add a new layer of rocks of about four hundred and fifty feet deep.

Besides this, enormous amounts of rock-salt deposited from the sea occur in various parts of the world. The salt mines of Wieliczka, in Austria, have been worked for more than six hundred years, and extend six miles in length, two miles in breadth, and have reached a depth of 1200 feet. Not only is salt found in the sea in these vast quantities and on the land in these massive deposits, but it is found in infinitesimal quantities practically everywhere; and one

of the difficulties of spectroscopic analysis is due to the ubiquity of the salt.

It seems most providential that sodium and chlorine occur combined in such quantities, and had such affinity for each other. If there had been no chlorine to combine with the sodium, the sodium would have stolen a great part of the atmospheric oxygen; and if there had been no sodium to combine with the chlorine, a suffocating gas with an unpleasant odour, poisonous to all animal and vegetable life and a bleacher of all colours, the chlorine would have rendered the world a lifeless grey desert. As it is, in combination the two elements are not only harmless to life, but essential to it. In the salty sea-water animal and vegetable life probably began, and blood of all animals and the sap of all plants contain salt, and it is probable, almost certain, that without salt no life could be. Certainly sodium and potassium salts play a very important part in stimulating the beating of the heart of animals. Harvey, for instance, found, when he was experimenting on the hearts of animals, that a heart which had ceased beating would begin to beat again if he touched it with his finger moistened with saliva, and the salts of sodium and potassium in the saliva were the stimulant.

The Part Played by Salt in the Realities of Health and the Fallacies of the Credulous

As an article of diet, salt is of considerable importance. Only animals that live on raw meat can dispense with it, and as soon as man became civilised enough to cook his meat and to eat cereals salt became a necessity. In ancient days it was not so readily obtainable as now, and many phrases and social customs and religious rites testify to the high esteem in which it was held. In the offerings to the ancient gods salt was always included; and when the superstitious person nowadays throws a little spilt salt over his shoulder to propitiate the fairies, he bears testimony to the vitality of old tradition.

Sodium occurs also in the form of sodium carbonate, sodium bicarbonate, sodium nitrate, caustic soda, and sodium sulphate. The carbonates are found in various mineral springs, and there are enormous deposits in Wyoming, California, and Nevada. Owen's Lake, in California, is estimated to contain from twenty to forty million tons of the carbonate.

The nitrate is the most important of nitrogenous manures. It is found almost exclusively in the Pampa de Tamarugal, a broad desert plateau in the north of Chili, between the Andes and the coast hills, and it is therefore known as Chili saltpetre. It has been formed during countless ages by the labour of the nitrifying bacteria in the soil, which have the wonderful power of extracting nitrogen from the air and converting it into nitrites and nitrates. Every year over two and a quarter million tons of Chili saltpetre are exported.

The Saltpetre that Feeds the Wheats that Feed the World's White Races

The great importance of this nitrate lies in the fact that it is the nitrogenous manure on which depends the fertility of the world's wheatfields; and that wheat is the staple food of the Western peoples, and probably through its phosphates the source of their superior intellectual activity. "We are born wheat-eaters. Other races, vastly superior to us in numbers, but differing widely in material and intellectual progress, are eaters of Indian corn (maize), rice, millet, and other grains, but none of these grains has the food value, the concentrated health-sustaining power, of wheat; and it is on this account that the accumulated experience of civilised mankind has set wheat apart as the fit and proper food for the development of muscle and brains."

To the labours of these nitrifying bacteria the white race is deeply indebted; and it gives us a very lively sense of the inter-relatedness of life to think that we should largely depend for our daily bread on a product of bacterial activity which we might never have discovered had not the trade-wind blown Columbus to America.

The Necessity of Utilising the Nitrogen of the Air for Growing Wheat

Year by year the wheat-eating peoples are increasing, and year by year must we depend more and more on nitrate of sodium to keep the wheat supply up to the wheat demand; and Sir William Crookes pointed out thirteen years ago that there is great danger of a wheat famine in the future. Only by increasing the productivity of the wheatfields by nitrate of sodium can the supply be kept equal to the ever-increasing demand. But even at the present rate of export, the supply of Chili saltpetre will soon be exhausted, and where will wheat-eaters be then? Without the nitrate we cannot possibly get enough wheat, and the exhaustion of the world's stock of fixed nitrates "means," to quote Sir William Crookes's words, "not only a catastrophe little short of starvation for the wheat-eaters, but, indirectly, scarcity for

those who exist on inferior grains, together with a lower standard of living for meat-eaters, scarcity of mutton and beef, and even the extinction of gunpowder."

Still, the case is not hopeless. There is plenty of nitrogen in the air; every square yard of the earth's surface has about seven tons of nitrogen gas resting upon it, and it is surely possible for us to convert it into nitrates, as the nitrifying bacteria do.

The Richness of the Air-manures which will be Secured in Time to Save Us

The fixation of nitrogen is the great problem of the future; and "unless we can class it among the certainties to come, the great Caucasian race will cease to be foremost in the world, and will be squeezed out of existence by the races to whom wheaten bread is not the staff of life."

Even already the problem is practically solved, for science has succeeded in converting the nitrogen in the atmosphere into various nitric compounds by means of electricity and also by non-electrical processes. It is almost certain that all the nitrogenous manures needed in the future will be manufactured cheaply and economically from the free nitrogen of the atmosphere. Sir William Crookes accordingly reaches the comforting conclusion: "The future can take care of itself. The artificial production of nitrate is clearly within view, and by its aid the land devoted to wheat can be brought up to the thirty bushels per acre standard. In days to come, when the demand may again overtake the supply, we may safely leave our successors to grapple with the stupendous food problem."

The Salt that has Given Tenfold Power to the Worst Human Passions

Potassium, like sodium, occurs in large quantities in sea-water, principally as the chloride and sulphate; it is also contained as carbonate in the ashes of all plants, hence the name of *potash* is commonly applied to the carbonate. The most important commercial source of potassium, however, are the Stassfurt mines, in the Prussian province of Saxony—an enormous deposit of sea-salts left there by the evaporation of a prehistoric ocean. Among the principal minerals containing potassium found in these mines are sylvine, or potassium chloride, the salt of potassium which corresponds to the chloride of sodium known as common salt.

Potassium is one of the elements of life, and neither animal nor vegetable life can subsist without it. But one potassium salt, saltpetre, is notably a salt of death, since, as is well known, it is the basis of gunpowder. Potassium carbonate is also much used in the manufacture of soft-soap and glass. Potassium iodide and potassium bromide are well-known medicinal salts.

Hardly any element that the earth contains is of such geological and sociological interest as calcium. The pure element is difficult to isolate, and was for long unknown, but Sir Humphry Davy's discovery of potassium and sodium soon led to its capture; and within the last few years new methods have been found of obtaining it, with the result that the metal has fallen in price from £110 to 12s. per pound Like sodium and potassium, it is far from a typical metal; it is comparatively soft; it has little lustre, and it readily tarnishes. As a pure metal, it has no importance; it is its compounds that make it illustrious.

It is found in Nature chiefly as carbonate of calcium, commonly known as chalk and limestone, and this compound has played in various ways a most interesting part in the biological history of the world.

The Chemical Compound that has Built Up the Higher Animal Life

Had the crust of the earth not contained sufficient lime to combine with a vast quantity of carbon dioxide as carbonate of calcium, the immense quantities of carbon dioxide at present locked up in the carbonate, which fizz out if we touch marble or chalk with vinegar. would have remained free in the atmosphere, with most momentous consequences to the climate of the earth, and to its animal and vegetable life. A great amount, no doubt, would have been absorbed by the sea, but still there would have been quite enough left to modify profoundly both the climate and the biological history of the earth. An excess of carbon dioxide might have favoured the growth of vegetation, and might have suited the lethargic reptilian life of the carboniferous period, but the higher mammals could not have thriven, and probably would have died in such a carbon-dioxide-laden atmosphere. To calcium, therefore, we owe higher animal life. Not only so, but without calcium the structural complexities of plant and animal life could not have been evolved. Calcium, in some form or other, is found in all plants, and all animals; and the shells of the lower animals and the bones of the higher animals sufficiently attest its architectural value.

The quantity of calcium that has gone to make skeletons, that is indeed still making skeletons, is almost incredibly prodigious. Chiefly in the sea does it play this part, and

A QUARRY ON THE BANKS OF THE THAMES WHICH ONCE FORMED THE OCEAN BED

Chalk, such as is seen in this quarry on the banks of the Thames, at Swanscombe, in Kent, is found in many parts of the South of England, and wherever it is found the place formed once the bottom of a sea, for the chalk is made up of the shells and skeletons of little creatures that are living only in the sea.

chiefly in the case of shell-fish and of these minute creatures known as foraminifera whose skeletons or shells go to form the deep-sea bottom. The deep sea is swarming with these little shelled organisms, and as they die they fall to the bottom and form a mud known as *the deep-sea ooze*. Night and day, century after century, there is a hail of these shells falling through the sea, and the sea-bottom is paved with these infinitesimal skeletons. How deeply they can accumulate the sea tells us not, but the land reveals the depth and extent of past accumulations, for much of the land, as we know, has been frequently at the bottom of the sea.

Over a great part of England, and a considerable part of Ireland, we find accumulations of chalk. The Needles of the Isle of Wight, the white cliffs of Dover, Flamborough Head, Beachy Head, are all white chalk; and though inland the chalk may be covered with later deposits, we have only to dig in any of the south-eastern counties to find it again. It does not stop at Great Britain; it covers a great part of France, Denmark, and Central Europe; it is found in North Africa, in the Crimea, and Syria, and extends as far as the Sea of Aral, in Central Asia. Altogether there is an area at least as great as Europe covered by the skeletons of these little oceanic creatures. On chalk London is built; on chalk Paris is built. Lebanon is chalk, Ararat is chalk, Sinai is chalk. In chalk is written, so that he who runs may read, the story of the oceanic baptism of much of the dry land. Chalk tells us that at one time south-east England, France, Germany, Poland, Russia, Egypt, Arabia, Syria were all under the sea, and as in some places the chalk is more than a thousand feet thick, some bits at least must have been under the sea for many thousands of years.

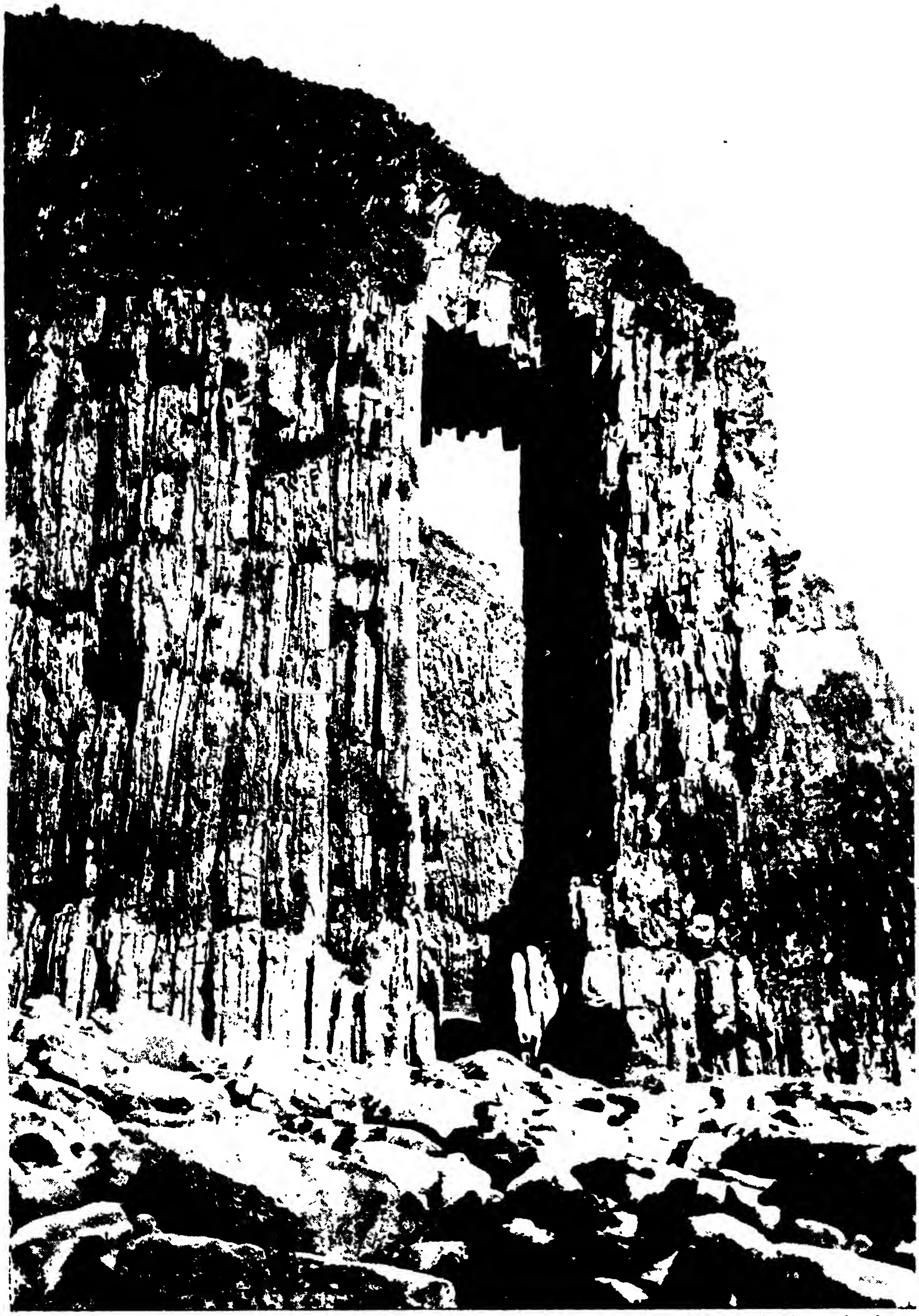
HOW LIMESTONE IS FORMED IN THE SEA
Many marine animals, such as are shown here, separate the carbonate of lime from the sea water and form their hard shells, which, falling to the bottom, are transformed later into rocks.

Chalk keeps for us, too, like flies in amber, the animals of the Cretaceous period, the last of the pterodactyls and ichthyosaurians, and plesiosaurians. Verily the chalk justifies its existence if only as a record on stone of the earth's history. Strange is it to think that man now uses the tiny skeletons of the chalk, sometimes to cure his diseases sometimes to clean his teeth, sometimes to whitewash his ceiling, sometimes to demonstrate a problem of Euclid. Strange that he should compound it with chlorine and use it to bleach his clothes. Stranger still that he should rub it on the tip of a cue in order to "screw" a ball made of the tusk of an elephant, which is itself largely composed of calcium.

Besides chalk, there are other forms of firmer rock, as the nummulitic limestone, composed mainly of little shells of foraminifera of the genus nummulites, that peopled in prodigious numbers the seas of the Tertiary period. These shells were plastered over the bottom of that ancient sea that once covered a large part of Europe and Asia. In time the sea bottom was raised into dry land and mountain ranges, and formed this so-called nummulitic limestone, which is several thousand feet deep in some places, and extends through the Alps, Carpathians, Caucasus, Asia Minor, Northern Africa, Persia, Baluchistan, and the Suleiman Mountains, even to China and Japan.

Much of the rock made of carbonate of calcium has been transmuted, by contact with molten granite and by pressure, into the crystalline form known as marble, that substance wherewith man has realised his highest architectural dreams. It was the Greeks who first exploited the marble mountains, but the Romans followed suit, and Rome, became eventually a city of marble. "But as for the mountains," wrote Pliny, "Nature has made these for herself as a kind of bulwark for keeping together the bowels of the earth; as also for the purpose of curbing the violence of the rivers, of breaking the waves of the sea, and so, by opposing to them the very hardest of her materials, putting a check upon those elements which never are at rest. And yet we must hew down these mountains, forsooth, and carry them off, and this for no other reason than to gratify our luxurious inclinations; heights which in former days it was reckoned a miracle even to have crossed. Our forefathers regarded

ORGANIC ACCUMULATIONS OF AGES PAST



This photograph represents the mass of vertical carboniferous limestone, known as the Horseback, on the Pembrokeshire coast. These rocks were formed ages ago at the bottom of the sea by the accumulation of shells and skeletons of many marine animals. The skeletons of all creatures are composed in great part of the same elements as these rocks, namely, carbonate of lime.

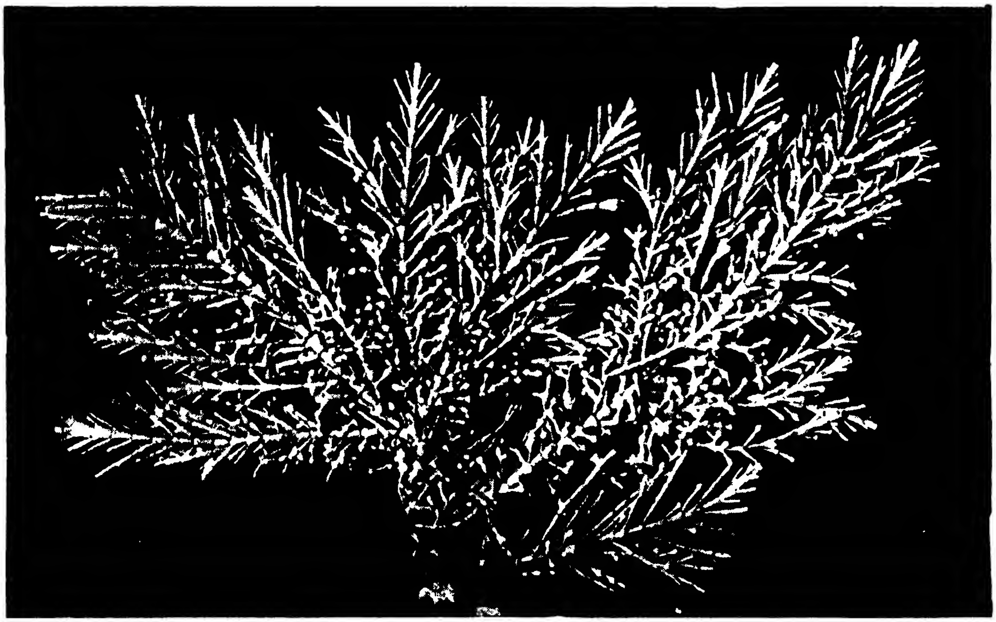
THE MARBLE MOUNTAINS AT CARRARA

This photograph of marble in its natural state was taken at the famous Carrara quarries, in Italy. There are many marble quarries in the world, as in England, Ireland, the United States, but none of them can approach the best Carrara marble. It is of this white, pure marble, eagerly sought all over the world, that most of the great masterpieces of the sculptor's art have been chiselled.

as a prodigy the passage of the Alps by Hannibal, and more recently by the Cimbri; but at the present day these very mountains are cut asunder to yield us a thousand different marbles, promontories are thrown open to the sea, and the face of Nature is being everywhere reduced to a level. We now carry away the barriers that were destined for the separation of one nation from another; we construct ships for the transport of our marbles; and amid the waves, the boisterous element of Nature, we convey the summits of the mountains to and fro."

Thus does Pliny describe the greed for marble in the Rome of his day. Everywhere were pillars, walls, baths, pavements of marble. It has been estimated that nearly half a million marble columns were landed at Ostia. Though the moralist may reprehend such ostentatious and extravagant marble magnificence, no can one deny that such marble buildings as the Taj Mahal, in India, and the Milan Cathedral are noble achievements; and when we remember that Pentelic marble was the material used mainly by Pheidias and Praxiteles, that the Venus of Medici was carved in Parian marble, and that the finest works of Michelangelo were wrought in Carrara marble, we realise the debt of Art to carbonate of calcium.

Marble formed of pure calcium carbonate is white. Mixed with iron oxides, it may be yellow, or pink, or red, and if it contain organic carbonaceous matter it may be blue-grey, grey, or black. Some special kinds of marble have received special names. So-called *onyx* marble is a banded variety of marble, arranged in bands of white, green, and grey colours. The alabaster of the ancients was a species of marble. In Devonshire a marble known as *madrepore* coral owes its beauty to fossil corals it contains. A very special kind of carbonate of calcium is the pearl which is secreted within the shells of various molluscs, the most valuable ones being those produced by the pearl-oysters and by the river mussels. Both of these owe their iridescence to the fact that the carbonate of calcium is gradually deposited in very fine concentric layers. The pearlies of the costermonger are in very sooth *mother* of pearl.



A PIECE OF CORALLINE FROM THE HAMPSHIRE COAST

Another special form of carbonate of calcium is coral, the hard structure secreted by many animals living in the sea, as the corals, polyps, sea-anemones, and others. In many cases, as is well known, coral accumulates so as to form coral islands and great reefs. The Great Barrier Reef of Australia stretches for 1200 miles.

Many of the corals are very beautiful, and the red coral of the Mediterranean is specially prized.

Our bones and teeth are made chiefly both of the phosphate and of the carbonate of calcium, so that calcium is their basis; and it is possible to write with a mammoth's decayed

ivory as with chalk. Marble, chalk, coral, ivory, teeth, pearls, bones, have all calcium as their basis.

We can hardly speak of the alkali metals without mention of the acids, nor of acids without mention of the alkalis. Indeed, we defined the alkali metals as metals with a special capacity for neutralising acids, by ousting their hydrogen, and taking its place, and we can define acids only as substances containing hydrogen which is ousted from its place by the metals with the formation of alkaline salts. Thus, nitric acid consists of hydrogen, nitrogen, and oxygen; and if a little sodium hydroxide be put in it, the sodium immediately displaces the hydrogen, and joins the nitrogen and oxygen to form sodium nitrate. Again, sulphuric acid consists of hydrogen, oxgyen, and sulphur; and if a little sodium hydroxide be added to it, the sodium immediately displaces the hydrogen, and joins the nitrogen and oxygen to form sodium sulphate.

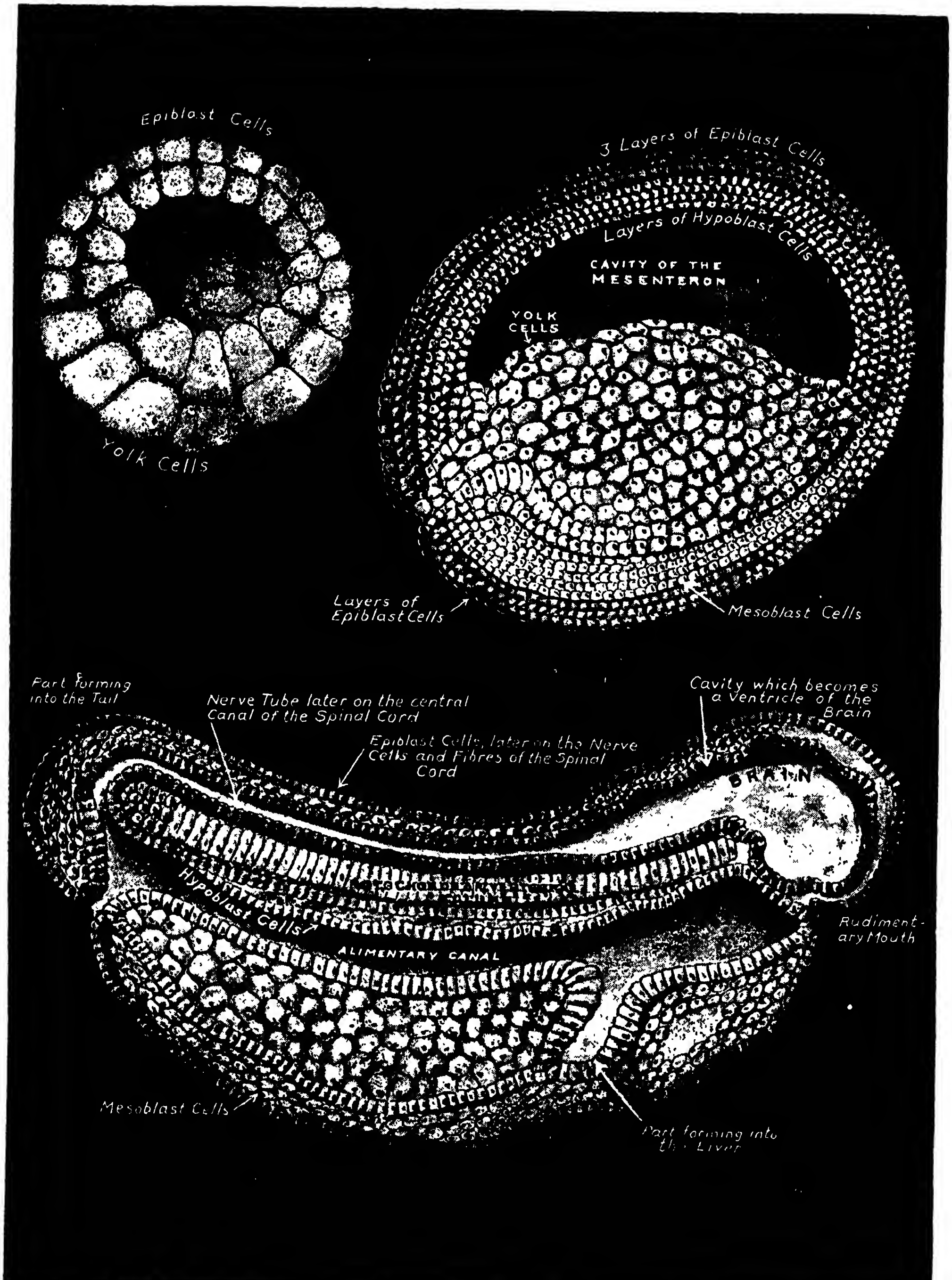
When Cleopatra dissolved the pearls in her wine, she performed an interesting little chemical experiment, proving that her wine was acid, and that the pearl was an alkali. It is not recorded, but if the pearls really did dissolve, they must have given off carbonic acid gas and made the wine fizz. If the wine was so acid as to dissolve pearls, it was quite a wise proceeding to neutralise the acidity with an effervescent alkali. All metals effect this substitution in acid, but the alkali metals are more soluble and effect the substitution more quickly and readily. All acids turn certain blue vegetable dyes red, and all alkalis turn certain red vegetable dyes blue, and this is often used as a test of acids and alkalis.

The principal acids are sulphuric, hydrochloric, and nitric acid; and the first plays such an important part in commercial chemistry that it is said that a country's prosperity may be estimated by its output of sulphuric acid.

A SCIENTIFIC EXPERIMENT UNAWARES—CLEOPATRA DISSOLVING A PEARL IN HER GLASS OF WINE

Cleopatra, to show her luxury and wealth before Mark Antony, dissolved pearls in her wine, not knowing that she was performing a scientific experiment that would improve the acid wine.

THE BUILDING UP OF ANIMAL LIFE



These pictures help us to understand the way in which living cells arrange themselves through the working of the mysterious forces of life into a complex organism. The artist has taken three stages in the early development of the embryo of a frog, beginning with the early cells, and showing how the three groups of cells—the Epiblast, Mesoblast, and Hypoblast cells—invariably produce certain specific parts of the organism. The drawing shows also how the brain, the spinal cord, the vertebræ, and the alimentary canal are among the earliest parts to form, and it illustrates the way in which these simple cells group together, and form countless parts of any individual member of the animal world.

THE UNFOLDING OF LIFE

The Tiny Cell which May Become an Oak or an Eagle, and the Astonishing Things We Know Concerning It

THE DEVELOPMENT & GROWTH OF THINGS

We know that there are living creatures which, from first to last, consist of only one cell; some of these we call plants, and others animals. We know, also, that other living beings are colonies of cells, all descended from a single cell; and that this single cell and its descendants may be called plants in some cases, and animals in others.

We require to study the processes by which a cell may grow into an animal or into a plant, and in either case into a member of a definite species—giraffe or whale, willow or oak, perhaps—but not a compromise between them. But, in the first place, we should be sure that we have clear ideas as to what we mean when we distinguish between plants and animals, just as we shall require distinct ideas—and more of them than our present knowledge suffices to supply—when we come to make the lesser distinctions between one species of animal or plant and another. In short, living beings all start from similar, though not the same, beginnings. They develop into evidently different creatures; and we cannot study their development without attempting to classify the amazing variety of forms in which we find that life embodies itself.

The first classification into plants and animals is the widest and deepest and most convincing, and that is what we shall deal with here, though we must never forget that the great principles of reproduction and sex, which we have studied, and the principles of development, which we are about to study, apply equally to the cell which will develop into an oak or the cell which will develop into a man. While we note distinction we must note similarity.

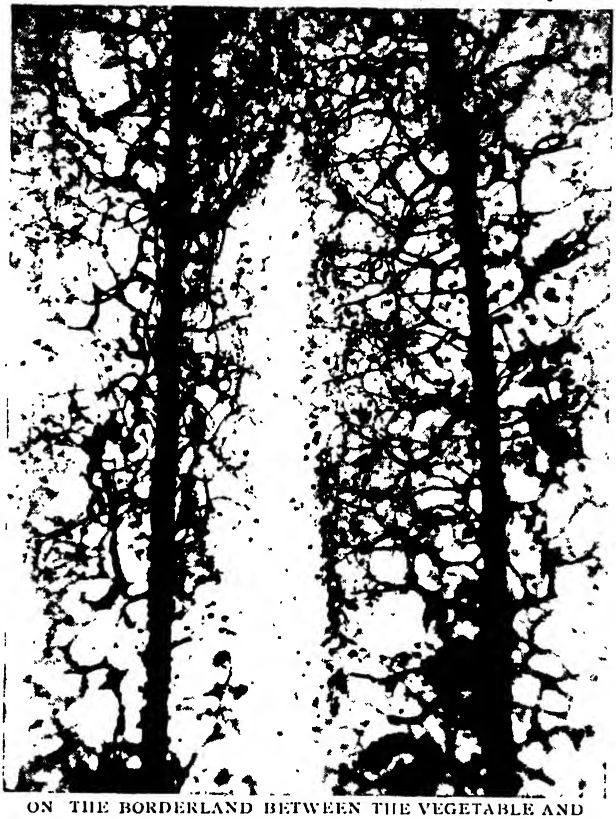
We have to admit that though the vegetable character of a forest, and the animal character of the tigers within it, are sufficiently contrasted—so much so that, in the past, vegetables have been but reluctantly credited with life at all—yet this evident contrast is less evident when we go back to beginnings. The statement is doubly true, and its double truth is to be noted, for each part of it supports and confirms the other, according to a great law of living nature—the law that the history of races, and the history of individuals, are similar in essentials. If we go back to the beginning of the tree or the tiger, the difference between them is incredibly diminished; if we go back to the origin of the race of the tree or the race of the tiger, we find, no less, that the contrast between animal and plant disappears.

Thus when we studied sex and the nature of germ-cells, and the laws of their formation and union, and the evident consequence of those laws, in the composition of the new generation, we had no need to say what species we were referring to. In truth, we were referring to big trees and big cats, to garden flowers and domestic "pussies" alike. The distinction between plant and animal, which is so tremendous in the adult, is of no account in the earliest stages of the individual. It is the strict truth that, under the microscope, we cannot distinguish between cells that will develop into creatures, animal and vegetable, which differ most palpably in their adult state.

This does not mean that the cells which have such a different destiny are the same, but it does mean that the different branches and twigs of the tree of life start from a common stem—or at least it suggests some such idea to the mind. The first students of these matters were amazed at the suggestion which forced itself upon them—that this astounding resemblance in origin and principles of development, which they found between creatures far apart in the

world of life, could scarcely consort with the idea of "special creation," and pointed to some community of origin, which we now express in the word "evolution." We are particularly to note the historical fact that the early study of development—that is to say, of individual development—could not but suggest a theory of the development of living species in general, which was later to receive the name of "evolution," and to make the greatest epoch in the history of thought.

Long afterwards, we are now able to put side by side, as a matter of course, and with vastly extended knowledge, the development of the individual plant or animal from germs so similar, and the development or evolution of races of plants and animals—nay, of all plants and all animals. And that is the comparison which allows us to assert a double truth in the statement that the contrast between tree and tiger diminishes if we go back to the beginnings. For we are now warranted in saying that tree and tiger, all plants and all animals, are of common origin, and we must attempt to define that origin, and the vital relation between these two great trunks of the Y of life.



ON THE BORDERLAND BETWEEN THE VEGETABLE AND ANIMAL WORLD

This photograph shows a small piece of a fungus-like organism, called mycetozoon or myxomycetes, which is found on rotten wood or decayed vegetation. These organisms are interesting, because in the early stages of their life they have the characters of animals, while in the latter stages they display those of plants, so that they cannot be definitely classified either as animals or plants. In the centre of this picture the young organisms are seen freely moving away from the mother plants.

The usual way has been to speak of the V of life, having one limb for the plants and the other for the animals. But we are satisfied now that the first forms of life, and many forms later than the first, no doubt, were essentially vegetable, however simple and humble, for they must have lived as true plants do, by taking food from air and soil, without needing the prior activity of any other forms of life. Animals, we know, cannot feed in this way. They live, one and all, upon the bounty of vegetable life. The animal world is, so to say, parasitic upon the vegetable, and the fundamental distinction between them is found therein. It is true that some vegetables live as animals do, depending upon the products of past life, or upon the living bodies of other creatures, for their food; but they are the exceptions that prove the rule.

Life, then, is like a rather lop-sided Y, of which the primary trunk is vegetable, as well as the thicker and more direct of the two stems into which it divided. At the point of division we find a whole multitude of different forms of life, which have developed from the primitive vegetable character into forms that cannot definitely be called vegetable nor yet definitely animal.

These "plant-animals," as they may on occasion be called, are of unique interest to the biologist, for they must be the nearest modern and extant representatives of the forms of life from which the animal world sprang. We cannot summon the most primitive animals from the past, nor is there any record of them, but we can study the present forms of life which are vegetable, and yet which are also animal; and which, therefore, from our former argument, we may look upon as, so to say, plants which have gone part of the way towards becoming animals.

These forms of life are neither numerous nor important, and we can understand why.

They have, so to speak, not made up their minds one way or the other; and accordingly they have been left behind in the race for life. Definite plants and definite animals are more successful, because they are more decided, and have avoided falling between two stools. The plants have gone their way, and the mighty animal kingdom, born of the primal plants, has gone its way, immeasurably transcending the vegetable world, because through the animal world and its evolution consciousness and mind have been realised in the world.

As we travel further along the two limbs of the Y, the divergence between the two paths of life becomes more apparent—as in the case of the tree, which is a very high type of plant, and the tiger, which is a very high type of animal. It becomes very evident that the plants have staked their lives upon one principle in special, and the animals upon another, and that, the farther each goes, the more must they rely upon the principle which has already carried them so far.

The plant and the animal differ, most fundamentally, in the direction to which they turn their vital energy. Both sexes are found, of course, among both plants and animals, and the characteristic difference between them is observed in both cases, but the characteristic difference in vital intention is found, a thousandfold greater, to be the very difference between the vegetable and the animal kingdom. Just as we saw the female of any species, plant, or animal, more conservative, more internally active, less externally active, more inclined to save than to spend, when contrasted with the male, which spends, struggles, strays, and is but little given to thrift—so do we find that the vegetable world constructs, builds up, stores, accumulates, lives in one place, and is thrifty, while the animal world spends its savings, roams, invents, and is never satisfied.

PLANTS THAT ARE ANIMALS AND ANIMALS THAT ARE PLANTS

At the point of division between the animal and vegetable world we find a multitude of different forms of life, which cannot definitely be called either vegetable or animal, for they possess something of the characteristics of both plant and animal life. The left-hand picture represents a branch of a plant-animal with numerous nodules, each of which is the home of a tiny polype. The centre picture shows a plant-animal gathering lime on its branches much in the way that many marine seaweeds do. The picture on the right is a much enlarged view showing how these organisms reproduce themselves by extending their tentacles and budding out new individuals

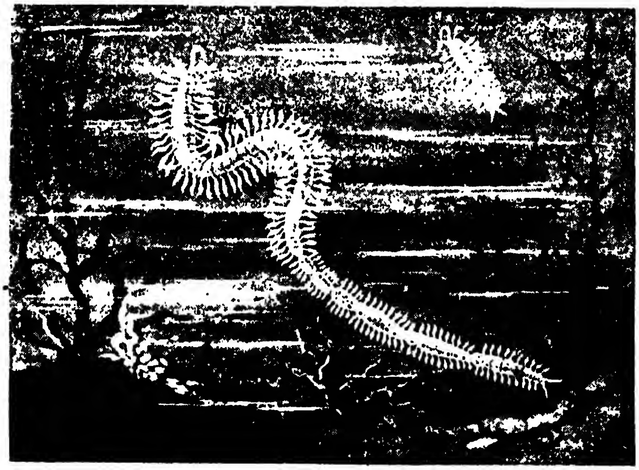
That is the essential relation between the two great branches of the living world; and as the two sexes are necessary for the future of any species, animal or vegetable, so the two great branches, animal and vegetable, are naturally necessary for the future. The plants could, indeed, survive without animals, but they could not go very far, and most existing plants would die. The animals could not survive at all, but would all die at once. Again we observe the analogy: we said that life was essentially female, and it is also essentially vegetable.

Animals as a whole, males as a whole, are later, and are essentially dependent; while plants as a whole, and females as a whole, can exist and reproduce themselves alone. But for the highest evolution and ultimate purposes of life both sexes of both animals and plants are necessary. The variety of interplay between these great branches of the living world is endless and inexhaustible. We need only remind ourselves of two salient illustrations—the formation by plants of chemical compounds which animals can consume, either directly, or tiger-wise, by eating the eaters of the plants; and the formation by animals of carbonic acid gas, which they pour into the air, and which is food for all the higher

forms of plants. Thus plants serve animals; and animals, though absolutely dependent upon plants, do serve the higher forms of plant-life—to say nothing here of the part played by animals, especially insects, in the fertilisation of plants.

Great though these differences be, the resemblance and fundamental identity of plants and animals is greater still. That is one of the lessons which the study of reproduction and of sex has taught us—perhaps the chief of its many lessons—for it demonstrates from a new view-point the unity of all life. And now we can define more precisely, and with a full appreciation of its scope, the great "law of recapitulation," which seems to lie at the base of individual development from germ to maturity. This is the law, commonly named after the great biologist Von Baer, which asserts that the development of the individual is a recapitulation—in epitome, much abbreviated, and often perhaps with many stages omitted or merged together—of the history of the race. We cannot usefully approach the problems of development, as we see them in plants and animals, nor can we appreciate the bearing of those problems upon the greater question of the origin of plants and animals and all their species, unless we take this key in our hands.

No doubt Von Baer's law has been worked to death; and the absurd straining of it, and the denial of facts which are inconvenient for it, have led many biologists to leave it on one side, but it is so evidently true when we look at development as a whole, and it has so often helped us in the comparative study and genealogy of different species, that we cannot do without it. Only we must not found upon it dogmatic assertions which lead us into a cloud of words, and which, until the revelations



A SEA-WORM AND ITS YOUNG

It is now admitted that variation, or the development of the various forms of life, both in animals and plants, depends upon the fundamental fact of sex. The study of those species which reproduce sometimes sexually and sometimes asexually is, therefore, very important. One of these species—the *myrianida*, a marine worm—is shown here, with several young that have been produced by budding attached to the end of its body. One has already broken away.

of Mendelism within the last decade, threatened to arrest the progress of biology, and make the name of Darwin a stumbling-block instead of a clearing axe for progress. That, unfortunately, is what was done by the "neo-Darwinians," who were so concerned with the law of recapitulation, and the law of natural selection, that they were in danger of a title to the motto which is always a sentence of death to any school of thought: No New Truths Wanted.

The law of Von Baer simply asserts that the facts of individual development can best be explained, where otherwise they beggar the imagination and the reason, by assuming that they correspond to the evolution of the race to which the individual belongs. As has been wittily said, the individual, in the course of its development, climbs its own ancestral tree. This is the central principle of the science of development, of which the proper name is embryology; and it is illustrated as well in the case of mankind as in any other species—better, indeed, for the process of development goes further, as the history to be recapitulated is longer. Of course, the facts do not countenance the popular statements, often to be seen in print in these days, that "the developing human being is at one time a fish, then a reptile, then a monkey." Yet even such a caricature of the truth does undoubtedly convey the idea which it exaggerates.

We find that the embryo of one of the higher animals, such as ourselves, is developed from a single cell, and is thus, at first, a one-celled creature, as its remotest ancestors were. We find, too, that at first its characteristics are quite as much vegetable as animal; indeed, it saves and constructs and remains in one place, very much after the typical vegetable fashion. Later it assumes forms which resemble

SIX STAGES IN THE LIFE OF A NEWT

All animals at the beginning of their existence undergo rapid growth and considerable change of form and structure. During these changes the young organism is either contained in the body of the parent or lies in the egg, until it is able to lead an independent life. These pictures illustrate the various stages in the development of a newt. In the first we have the eggs of a newt attached to a water-plant; in the second and third we see the young newts taking shape within the eggs; in the fourth the newts have just emerged from the eggs; in the fifth they begin to develop their gills; and in the sixth picture we see the young newts six weeks old. (Photos by J. J. Ward.)

types of the kind called plant-animals; much later it develops gill-arches and other structures after the fashion of a fish; and only when it is born does it become an air-breathing animal.

Thus, the law of recapitulation is in general justified; and detailed study, alike of the higher animals or the higher plants, is rewarded by copious evidence of stages, in the course of their individual development, which resemble, in their sequence as in themselves, the probable stages in the long evolution of these types from lower forms. Innumerable peculiarities, not only in the immature but also in the adult individual, find here, and nowhere else, their explanation.

For instance, the human embryo at one stage has a considerable tail; and the inconvenient fact that we are liable to choke, because our food and drink have to jump past the opening of the windpipe on their way to the gullet, is explained by the relative position in the fish of the gullet and the swim-bladder, from which the lungs of the air-breathing descendants of fishes have been developed. Here, and in countless other cases, the higher plants and animals, including men, may find "ancestral relics," and evidence of "the base degrees by which they did ascend."

THE HALF-GROWN AIR-BREATHING STAGE OF MALE SMOOTH NEWT

FULL-GROWN MALE SMOOTH NEWT WITH FLOWING CREST DEVELOPED

It was the law of Von Baer, together with the assertion and demonstration of this master embryologist that development proceeds from likeness of parts to difference of parts, which helped Herbert Spencer towards the enunciation of the law of universal evolution, and towards his invaluable study of the principles of life and its progress. That is why we must have some appreciation of the facts of development before we can approach the principles of organic evolution and the origin of species.

Let us now return to our starting-point, and look more closely at the amazing cell from which a perfect animal or plant is about to develop. We can recognise the chief lines of its structure, but we cannot peer into the finer lines which make the detail and the difference, much less into the chemistry, which lies deeper still. So far are we from seeing the adult being in the germ that, as a rule, we cannot distinguish the germ of one animal from another, or even that of a plant from that of an animal. Long ago, as time goes in the history of science, men thought that, for instance, the miniature chicken could be found in the fertilised egg of the hen, and there are even drawings extant which depict this little chicken as it was thought to be seen within the egg, under such lenses as were then available. Nothing of the sort is to be seen. Development is not an unfolding and magnification of a tiny model of the forthcoming being; it follows the lines suggested by Von Baer, and resembles one form of life at one time and a different form of life at another time.

Nevertheless, there is one way in which we can tell what a new nucleus, or germ, or zygote, will develop into—and that is by finding out where it came from. If it came from the union of gametes provided by a pair of fowls, it is uncommonly likely to turn out a chicken. "Like begets like," as the old saying goes. Somehow or other, in that indistinguishable cell, there

lie the "promise and potency," the form and destiny, of an oak and nothing else, an elm, a fly, a horse, a human being, and nóthing else. In general, that great fact is what we shall afterwards study more critically under the name of heredity. And one reason why more criticism is needed is that, though like begets like, it never begets exactly like. The offspring are not identical with either parent, and they are not identical with each other—except in the case of "identical twins," which arise from a single cell, and prove the rule, as we shall later see.

The Constant Occurrence of Variation in the Infinitely Small

This difference, accompanying the likeness, is called variation; and our general survey of reproduction and of sex is incomplete unless we ask one further question: Is it the mixture of the sexes that causes this variation? Do we find as much variation, or any, in the offspring of those species, animal or vegetable, in which sex does not exist? Evidently the answer to this question will be of enormous importance, in itself, and in its bearing upon the whole theory of evolution, for it will involve, in large measure, the answer to the general question: What causes variations?—and to the no less important question: What is the function of sex?

Now, we cannot doubt that variation occurs even in asexual reproduction, or reproduction "without sex." If we try to imagine how complicated the internal structure of even a microbe must be, we may well believe that in its most careful splitting to form two new microbes, not exactly the same quantity and quality of every constituent and structure shall be apportioned to both. But if the apportionment be not exact to the very uttermost, then each of the two new microbes, though in the main the same as its fellow and its parent, yet must differ from both; variation will have begun already. Plainly, therefore, it would be absurd to suggest that there could be no variation if it were not for sexual reproduction.

The Fallacy of Study from One Point of View Without Seeing All the Facts

An excellent opportunity for deciding whether sex favours variation would appear to be furnished by those species which reproduce sometimes sexually and sometimes asexually. We can study the offspring of the one parent alone, and see how much they differ from their mother and themselves; and we can then study the offspring where the female gametes have been yoked with male ones, and where, as we should expect, the offspring ought to differ more among themselves, and more from their parents, than in the former case.

This mode of inquiry, which seems so straightforward and satisfactory, has been adopted in the study of various bi-sexual species in which the females are capable of parthenogènesis, or reproduction without fertilisation. Unfortunately, the work has been done from a purely mathematical point of view, by workers who were ignorant of the fatal fallacy which requires to be avoided at every step in all such inquiries as these. They noticed and measured differences in the offspring in the contrasted sets of cases, and assumed that these differences were really variations, due to original, native, inherent differences in the nuclei from which they were developed. But no one has any right to make any such assumption until he proves that what he is dealing with is not merely the difference due to different nurture.

The School that Holds that Variation Does Not Depend Upon Sex

Plants that are essentially and germinally similar may exhibit all manner of differences, say, in longevity, to mention nothing else, according to whether they are watered or not watered, grown in soil or sand, in the sunlight or in a cellar. If we examine a number of specimens of any species, we thus find that they differ, partly because they are different from their very germ, and partly because no two of them have had exactly the same nurture, food, air, light, and so forth. The first kind of differences are true variations, and the second, of relatively trivial importance, are called fluctuations in the recent terminology which has so quickly established itself in the minds of modern students. The "biometricians," or "measurers of life" (the immeasurable), ignored this vital distinction, and measured fluctuations when they thought they were measuring variations.

They found that certain differences between offspring were the same whether they were produced by one parent or by two—which we should expect, realising that the differences in question were due to nurture and had nothing to do with parentage; and they concluded that it is impossible to accept the "view that one of the results produced by the differentiation of animals and plants into two sexes is an increase in the variability of their offspring." Thus,

in the words of Prof. Karl Pearson, the most distinguished representative of this remarkable school: "Variability is not a product of bi-parental inheritance. Whatever be the physiological function of sex in evolution, it is not the production of greater variability."

The School that Holds that the Function of Sex is the Production of Variations

Nearly all the students of this subject, including the present writer, who takes this opportunity of trying to undo the inaccuracy of the past, were led at one time into following this view, little realising what was the real nature of the material upon which such conclusions were based. No one who has acquainted himself with a single fact of Mendelism requires to be told that these conclusions are notoriously in contradiction with the exact evidence, daily more copious, which the present century has already gathered. Indeed, the rediscovery of Mendelism in 1900, and the work done since, restore biological thought, after an aberration which now seems incomprehensible even to those who shared it, to the position which the pioneer work of Weismann had indeed established, after Mendel's work was done, and before its rediscovery.

This honoured veteran of biology, August Weismann, of Freiburg, has indeed lived to see his work, in its broad outlines, established more firmly than ever. He long ago maintained, as the result of his arduous and original research upon germ-cells and their behaviour, that the evident cause of variations in all living species except the very lowest is the intermixture of two somewhat dissimilar germ-plasms in the act of bi-parental or sexual reproduction.

The New Lessons Brought to Us by the Rediscovery of Mendelism

As the present writer stated it several years ago: "Each gamete *loses* half its chromosomes, and the new cell formed from the two thus contains only a portion of the (former) elements of each. The natural supposition was that there is a germinal selection of parental characters; some are taken, others left, and hence the new individual must vary from either of his parents, and need by no means necessarily strike an average between them. In other words, the function of sex is the production of variations; and the known facts seem to afford a ready explanation of the manner in which such variations arise."

As we now see, in the light of Mendelian experiments, it is the precise, particular, unique combination of the two parents that determines the character, often utterly new, of the offspring; and the facts known to Weismann thirty years ago are multiplied and amplified manifold. We shall see elsewhere that this is far from being the only instance where men of science have been compelled, by the most recent work, on Mendelian lines, to return to older views which the acceptance of "biometry," a decade ago, seemed to have disproved.

The development of the various forms of life, of plants and animals in their great contrast, and of the various kinds of plants and of animals, in their lesser contrast, is thus seen to depend all-importantly upon this fundamental fact of sex; and we are able to answer, with some certainty, and with far more evidence than was ever available before, the question of the function of sex. It is a twofold but single function. First, as we have seen, the function of sex is the division of labour, through the development of one germ into a male organism, with its peculiar powers, and of another into a female organism, with its peculiar powers. Each without the other is incomplete, as we suggest when we speak of a man's "better half." The life of the species is divided between them for its furtherance, and is entire in neither.

The Union of Two the True Solution of the Variations to Follow

This division of labour serves the present, and it serves the future, for which the present, in the scheme of Life, always exists. The parental characteristics are co-ordinated in the care of the offspring—as when the mother nurses and the father provides. But this subdivision of labour, and this service of sex to the future, goes deeper still, for it is concerned with the construction of ever-varying types of creature, some of which are an advance upon their parental and all remoter ancestors. Thus evolution is made possible. The division of labour shows itself in the making of the new nucleus, which is half maternal, half paternal in origin, and which is therefore veritably new. Palpably asexual reproduction could not compare with such a process in the production of variations; and it is only one more example of the power of authority that the contrary view could have been successfully imposed, for however short a time, upon the minds of students.

Sex is thus "justified of her children"—*i.e.*, by her children; and the fundamental idea of the "physiological division of labour," which we owe to the French

physiologist Henri Milne-Edwards, receives a further extension.

The details of individual development are thus reviewed with new eyes when we look upon the individual in question as a zygote, a double being, half paternal, half maternal, in origin and constitution; and we find, as is the glorious rule in science, that the old facts shine with a new light by reflection from the new ones. That is why embryology, the study of individual development, which seemed, only twenty years ago, to have become exhausted, has taken on a new lease of life, in the light of the new idea that each individual is at once old and new, one of a multitudinous species, and yet unique, because of its double origin in two cells—really two half-cells, for they have only half their essential substance—which have never met before, and will never meet again.

The details of embryology, as seen in this plant, this animal, or that, are innumerable. They have been most closely studied in familiar creatures such as the chick, and their principles are similar in widely contrasted forms of life. The single cell of double origin itself divides into two—not the two whence it was fused, but a new two, each containing both paternal and maternal matter.

What the Study of Embryology has Revealed in the Study of Vertebrate Life

These re-divide until we find a ball of cells, a ball which grows and becomes a hollow sphere bounded by a single layer of cells. This layer becomes double; and later a third layer appears between them. From without inwards the three layers are called epiblast, mesoblast, hypoblast. In the case of the chick or any of the higher vertebrates, we can trace an orderly sequence in subsequent stages.

Thus the skin and the nervous system are always found to be developed from the epiblast, the muscles, bones, and blood from the mesoblast, and the lining of the digestive tract, except just at its extremities, from the hypoblast. Various names are given to some of the stages, as, for instance, the ***morula***, or mulberry stage, to that in which the young embryo consists of a ball of cells like a mulberry. Embryologists have devoted long years of labour to describing all the possible details in all manner of species; and the foregoing brief description outlines the gist of their findings, and indicates the point at which they had arrived, and where they themselves thought that they must remain until the new study of germ-cells and their formation and union began.

This new study involves a new embryology, which no more supersedes the old than the new astronomy or psychology supersedes the old, but which adds to and enhances and reconstructs the former knowledge. We learn that though, as has been insisted, we must distinguish between the essential facts of reproduction and the facts of development of what is reproduced, yet the development depends upon what the germ-cells have brought with them to be developed.

Why the Offspring Resembles the Parents and Yet is Different from Them

Embryology and heredity thus come close together; and we study development from our knowledge of the germ-cells, whereas formerly we could only study it from the point of view of the finished being, which was all we knew about. We see that the plant or the animal becomes what it is because it is the development of material of a special kind with a special origin.

We begin to see why the new creature resembles its parents, because it is developed from the same kind of germ-cells as they were; and yet also why it exhibits variation, and does not *exactly* resemble its parents—because it is developed from a unique combination of germ-cells, and therefore must be its original self, though it is still its "father's son" or "mother's daughter." This is often a hard lesson for human parents, but there it is.

In short, our successive study of reproduction, sex, and development has resulted in an appreciation of what is meant by variation, and of the orderliness and necessity and universality of variation, and even of the cause of variation, such as not even Darwin and Spencer were able to anticipate.

The Facts that Darwin Never Knew, though They Were Known

It is an advantage, as anyone may realise who reads Darwin's chapters on variation and remembers that Mendel's work was already published, and that Darwin lived and died without ever having heard of its existence, to know which he would have given years of his life, one cannot doubt. All that is an unexampled episode in the history of science, which we must study elsewhere. Meanwhile we have the excellent fortune to approach the centre and key position of our subject with definiteness of microscopic knowledge and experimental illustration, above all as regards reproduction, sex, and development, which should help us incalculably to realise what is meant by organic evolution.

THE PLEASANT TOIL OF THE COUNTRYSIDE

AUTUMN PLOUGHING—AFTER THE PAINTING BY GEORGE CLAUSEN, R.A.

PLOUGHING THE VAST PRAIRIE LAND OF CANADA

The upper picture is reproduced by courtesy of Mr. E. C. Harris, the owner, and the lower picture by permission of the Canadian Pacific Railway.

BREAKING UP THE SOIL

The First Ploughmen of the Earth—The Marvellous Work of Worms and other Burrowing Creatures 7883

THE DEADLY BATTLE WITH THE WEEDS

If we want to refer to a date before history we speak of the time "when Adam delved and Eve span"; and digging must have been one of the very earliest of men's labours. There were, and, indeed, still are, some wandering tribes who gather what the earth produces of itself, and as soon as that is exhausted pass on to another haunt, just as birds do when they migrate from England at the time when insects fail, and pass to the warmer Southern or Eastern lands. But in most places men soon found out that the wandering or nomad life did not suit them best; and at the same time they made up their minds that certain plants, not very many in number, made better food than others.

As a rule, these could not be grown in large enough quantities unless men delved as perhaps Adam delved. Of course, there are some countries where digging or cultivating the ground is not practised. In that wonderful country around the equator in West Africa, banana-trees grow so luxuriantly that man has little more to do than to pluck the fruit. He can make string of the leaves, and get the very best food, and even wine, out of the fruit. In the same country the grasses grow several yards high, and the moist heat keeps up a fertility which leaves man little or nothing to do in the way of cultivation.

It is so, perhaps more so, in the desert regions where the date palm springs from the sand. But the further from the equator you go, the more necessary becomes this art of delving. One reason for this is that many, if not most, of the things men grow for food in the regions distant from the equator are not native or natural to the country. In colder countries this generally means that directly the plant is left alone it disappears.

A very interesting experiment to test this was made some years ago in Hertfordshire. A field of wheat was sown and left to seed itself. In this way, of course, ever so much more seed fell to the ground than would have been sown in the ordinary way, but in spite of this quite a small amount of wheat grew up the next year, only an ear or two in the following season, and in the next not one plant of wheat could be found.

Precisely the same thing would happen with most of the field crops and the various vegetables that we grow in our gardens. They disappear, because the so-called weeds and native plants are too strong for them and kill them off. It is a question of the struggle for life of which Darwin and Wallace wrote; and in the world of plants those disappear, or almost disappear, which for one reason or another are less well suited for the struggle in any particular district.

Such a hardy-looking shrub as gorse would soon disappear from a chalky valley, and the vigorous hemlock would not live a year in a Surrey garden. Much more would our cultivated crops die out before the native weeds. But in cultivated fields and gardens we save these plants from the struggle. We give them the conditions they like best, and we use all sorts of methods to save them from the need of struggling. Root crops are planted largely because the cultivation of them clears the ground of weeds; and along with such a crop as lucerne we sow grain in order to smother out the weeds, which in the first year might be too strong.

Ploughing has, of course, other effects than discouraging weeds and saving the pampered wheat from the struggle for life. It is little use putting seed into the ground unless the surface is loose and well aerated. The plough or spade breaks up the soil tc

the weathering influence of the air, rain, wind, frost, and dew, and enabling it in this way to crumble up so that a soft and easy bed is made for the precious seed.

Probably half the people who plough and dig do not realise nearly all the reasons for the work. One most important reason is to keep moisture in the ground. If rain falls on an unbroken surface a great part of it either runs off or evaporates. But if it is deeply ploughed—as some very pretty experiments have shown—something like a third of the moisture which falls is held by the ground. 71883

One of the great discoveries in the way of cultivation in recent years is the method of what is called dry-farming, which might, perhaps, be as well called wet-farming, since its object is to keep and use what moisture there is. This new art, which may be briefly described, has transformed, in America, Africa, and Australia, huge tracts of land, which used to be quite barren, into fertile fields. There are different devices and processes, but the essential secrets are not more intricate than rolling and hoeing.

After it has been ploughed to a depth of at least ten inches, the ground in which the seed is sown is rolled and compressed as tightly as could be for exactly the same reasons as wheat is rolled in an English spring. And the reason is this: the ground, acting much like a sponge or a lump of sugar, or blotting-paper, will draw water up to the very top from very great depths if it is all fairly firm and in a certain state. The water passes by what is called "capillary attraction" from particle to particle until it reaches the surface. If it is allowed to get so far, it, of course, evaporates, and from the point of view of the farmer is wasted.

In very dry countries the problem is, first, how to get the water sucked up from the depths; and secondly, how to prevent it being wasted when it comes up to the roots. Rolling brings about the first object on many soils. It could not, of course, do this if there were a layer of gravel below which would entirely prevent the attraction of water. But in general, if deeply ploughed ground can be thoroughly compressed, some small amount of water will reach the surface from a very considerable depth.

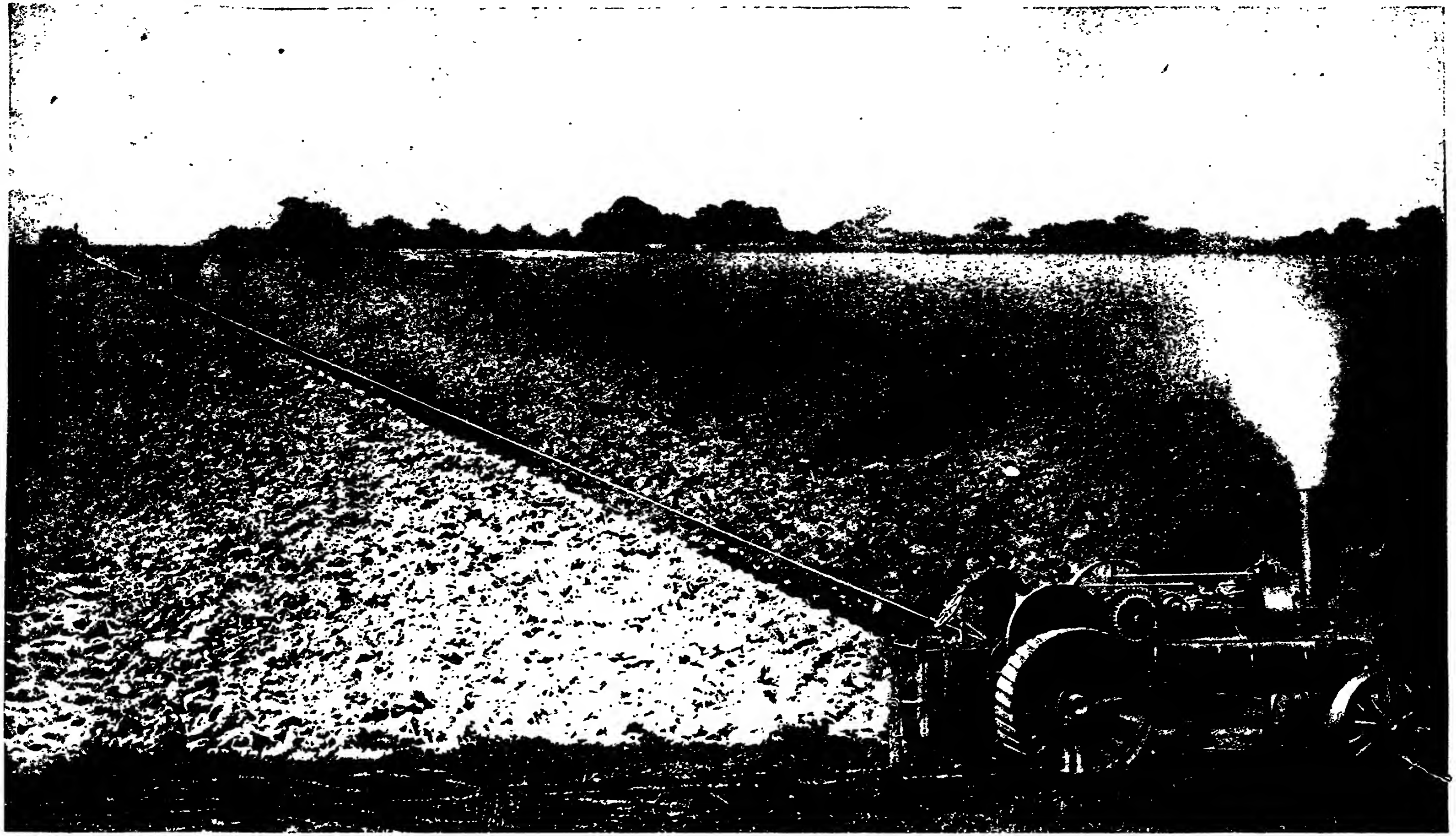
The next step is to roughen the surface. If the compressed earth can be covered with a loose, friable, carious layer of earth or even stones, the upward movement of the water

THE FIRST PLOUGHMEN OF THE EARTH—WORMS AND THEIR CASTINGS

A GREEN CARPET FOR A STONY FIELD

Near Darwin's house in Kent was a slope, which Darwin's boys called the stony field, because tl stones clattered as the boys ran down it. The field was left alone for thirty years, and by that time horse could gallop down the slope without touching a single stone. The worms had brought up ear from beneath, and prepared a carpet of beautiful tur'. These photographs illustrate what happene

THE STEAM ENGINES THAT ARE SUPPLANTING HORSES IN PLOUGHING



A CULTIVATOR-PLOUGH BEING DRAWN ACROSS A PLOUGHED FIELD BY A WIRE CABLE WOUND ROUND THE DRUM OF AN ENGINE

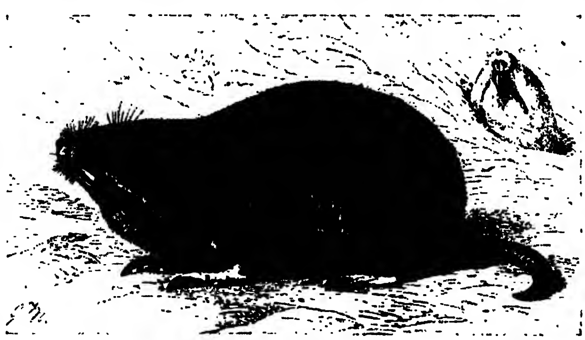
will quite cease. Half the object of hoeing a garden is to form such a loose surface in which "capillary attraction" does not work because the particles of earth are not close enough in contact. If we pick a stone up from a ploughed field on any frosty day we shall find underneath it a white accumulation of hoar-frost. The moisture from below has got so far and could get no farther. Just so if we dust aside the loose top layer of the dryest-looking soil, we find, as a rule, quite a moist layer underneath.

There are some fields which would become very much more fertile if they were half covered with stones; and in practice English farmers find that in the flint country the fields with most stones need the least manure. Dry-farming, which has made deserts blossom like the rose, consists in alternate rolling and what may be called roughening, a feat accomplished by some ingenious machines which partake of the virtues of a plough, a harrow, and a hoe. The rolling brings up the moisture from the depths, the "hoeing" keeps it near the level of the roots and prevents evaporation.

Of all the elaborate ploughs and cultivators that men have designed, none is quite the equal of the original cultivator, the earthworm. Many people know that fascinating book, written by Darwin in his old age, on the work of the earthworm. He showed that in quite a short time in certain favourable places all the top-soil passes through the bodies of worms. They, indeed, perform every act of cultivation which the land desires. First of all, it needs aerating to as great a depth as the roots can penetrate. For this purpose it is the practice of farmers to use what are called cultivators, generally machines in which a number of crooked arrow-headed spikes—resembling the fish-hooks of a child's first writing-book—are dragged by steam through the soil without bringing the bottom soil to the top.

But the passage dwellings of the worms go even deeper than these cultivators. The worms play the part of the harrow and the weather combined in reducing the earth to the fine and settled consistency which best suits the seed or covers the grass with the finest manures. The worms drain the soil and plough it, and increase the speed at which the leaves are reduced into the state of plant food.

Worms may well be call the first ploughmen, but Darwin was wrong in supposing that they were found all over the world, or that rich black loam was impossible without them. There were at first no worms at all on the fertile plains of Manitoba, where the best wheat in the world grows on some of the best land. Certainly that rich black virgin soil has been formed without them. But their part has been taken by another primitive ploughman, called in Canada the pocket-gopher. This curious and wonderful animal, which is a sort of mole, performs wonders of ploughing and harrowing even beyond the scale of the worm.



THE COMMON POCKET-GOPHER

This little American animal does for the soil what the earthworm does in this country. These rodents bring to the surface vast quantities of soil, which they disintegrate and mix with dead vegetation, resulting in the production of a rich and fertile black loam.

Numbers of foreign critics said at first of Darwin that he was writing foolishness when he published his book on worms, but they soon came to see the immense importance of the facts; and it is very curious that none has done for the mole what Darwin did for the worm.

A Canadian professor once wrote: "The formation of the vegetable mould in these regions must therefore be due to some other agency than that of worms, and this I believe to be principally the moles, which live in vast numbers throughout the region in question, and, although apparently insignificant animals, accomplish more in the way of soil-making than the earthworms of England. If the fertility of ten millions of acres of land in the North-West, and consequently their value, has been mainly due to the work of moles, these apparently insignificant little creatures may be regarded as the most important of the native animals of the country."

The English mole, although it is not a favourite with farmers, does work hardly less wonderful in amount; and must be reckoned with in any account of soil-making. The greater part of what is said of the gopher in Manitoba will apply to the mole in many

MONSTER MACHINES THAT MAKE LAND FERTILE

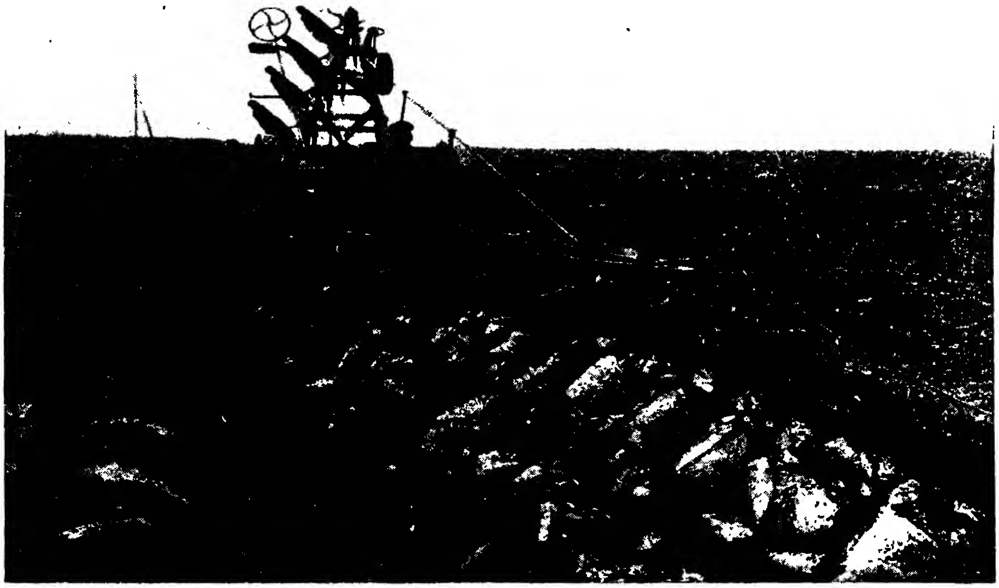
THE "KNIFER" REMOVING ROOTS AND ROCKS FROM VIRGIN SOIL IN HAWAII

A TRENCHING-MACHINE AT WORK

A FINISHED IRRIGATION TRENCH

A POWERFUL PLOUGH THAT BREAKS UP HEATH LAND FOR FOREST CULTIVATION

PLOUGHING UP LIGHT & HEAVY SOILS



A CABLE-HAULED DEEP PLOUGH AT WORK ON HEAVY CLAY LAND

A REVOLVING DISC-PLOUGH TURNING OVER LIGHTER SOIL AFTER THE HARVEST

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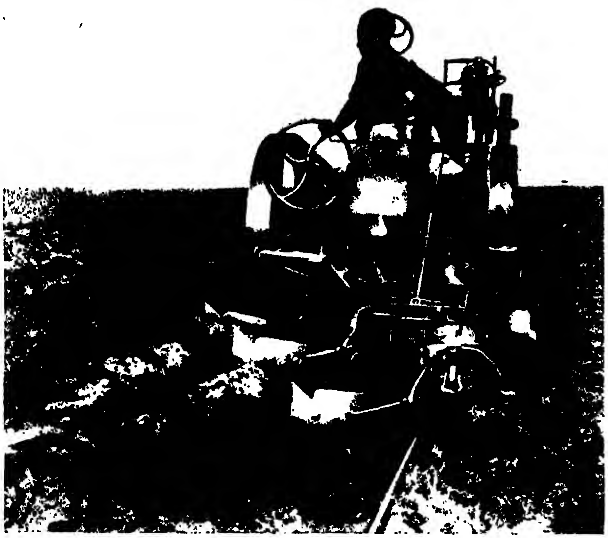
English counties. Their numbers are enormous. A thousand were recently killed in a week or two on a small English estate where they were destroying the grass fields; and great stretches of Essex fields may be seen so covered with mole-workings that it is next to impossible to walk a hundred yards without treading on many heaps.

Happily, the pocket-gopher has been thoroughly studied, especially by Mr. Thompson Seton, who holds the curious but worthy post of official naturalist to the province of Manitoba. In his history of Manitoba mammals he writes: "Darwin concluded that the earth-worms in five years bring up soil enough to cover the ground one inch thick, and that, therefore, the result of its labour is of vast importance. I reckon that the pocket-gopher does this much in five months. It does not do it in the same way or so effectively, because the earthworm actually digests the substance of its castings, but it is evident that the gopher's method answers the purpose of fully disintegrating and mixing the dead vegetation with the soil to produce a rich and fertile black loam. From these observations we may form some idea of the work done towards tilling and draining the ground by this continental army of rodents; and it is possible that they cause still greater changes by bringing such vast quantities of soil under the influence of the sun and wind.

"Their aggregate power as active geological agents must be immense; and when we stand on the banks of the Mississippi, and watch that turbid river bearing its four hundred thousand million tons of mud per annum to the sea for the manufacture of new continents, we should realise that a great many thousand million tons of that flood-borne silt is simply the débris from the workshop of the *Geomyidæ*."

It is a far cry from the first ploughman or even the primitive instruments of men to the latest ploughs now used. The biggest of these are worked by two steam engines hauling the ploughs by a wire cable. Some of these plough no fewer than twenty-five furrows at a time; and work so quickly that they can finish a hundred acres in as short a time as a primitive labourer could plough one. The advantages of all these quick and highly developed machines from the plough to the reapers are many. One is that a farmer can always take advantage of the weather. He can do what he wants with such speed that he is certain afterwards to find suitable periods for sowing and performing other necessary operations.



MODERN MACHINERY BREAKING UP THE FACE OF THE DARK CONTINENT

A breaking plough at work in cane stubble land at Mopea on the Zambesi River

Further, the work is done very much more cheaply. And in this respect the vast combination machines which can at the same time reap and bind and thresh show yet more remarkable results. All these machines are not perhaps in many ways more effective than men's hands. The best work is still done with the spade. But since the early days when a great part of the population was at work on the land it has become harder and harder to get workmen enough for the land; and without these time-saving machines it would be impossible under present conditions to get a sufficient number of acres ploughed and sown to supply the world with corn. Nor, again, would it be possible to bring new lands into cultivation, or "under the plough," as it is called.

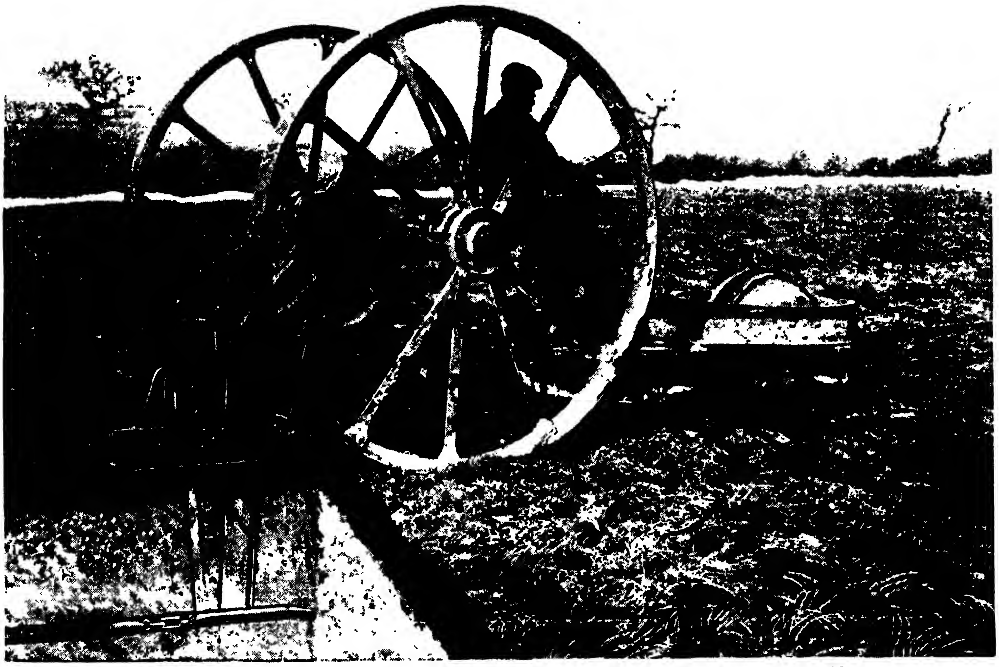
There are ploughs which cultivate—that is, break up the under-soil without bringing it to the surface, at the same time that they turn over the top-soil. But the ordinary marvel of the most modern ploughs and agricultural machines is their power to reclaim land from a barren to a cultivated state.

A most striking account was given in a German newspaper of the breaking up by the use of a "Fowler trenching plough"

used in an area of suburban land devoted for tree-planting. At the end of the description comes the following passage: "The stones break with a crack, and are slowly but surely forced out of the upper edge of the furrow by the mould board. Colossi of from 1000 to 1650 lb. are then thrown up like mere sods. Only engines of powerful build and solid construction can perform such a task. The trench is made quite smoothly, and the whole work proceeds so noiselessly that the humming and puffing of the working engine can scarcely be heard."

Another account, not less remarkable in its way, is given of the draining of some marshy land in North Africa: "About ten years ago an Algerian swamp, once a favourite resort of sportsmen, and also a source of malarial fever, was converted into vineyards or cornland. The task of effecting the drainage was extremely difficult, as the ploughs sank repeatedly into quagmires, and special causeways had to be constructed to bear the engines, but eventually the land was deprived of its surplus moisture, and, by a succession of operations, made to produce fine crops of grapes and corn. It is certain that such work could not have been carried out by hand labour, except at a cost which would have deterred anyone but a wealthy philanthropist from undertaking the enterprise."

We now have machines which will do almost all the work of hands with the highest manual skill. Everyone knows the ordinary corn-drill whose use has almost entirely driven out the old method of broadcast sowing which made weeding quite impossible. But now we have machines which do every kind of sowing work, of weeding work, of cultivating work. There are machines which drop single seeds, such as beans, or tubers, such as potatoes, into holes most neatly drilled to the right depth for their reception. There are machines which cut right underneath roots and "lift" them. There are machines which dig potatoes and toss them clear of mud into nets; others which will cut drains and trenches of any pattern that may be desired.



A MACHINE WHICH MAKES DRAINING TUNNELS BENEATH THE SOIL WITHOUT TURNING OVER A SOD

One is inclined in these days to think that there is no limit to cultivation. On the American continent it is astounding to see the speed with which a piece of waste land or forced land can become a field. There are instruments for rooting up or dragging up trees and brushwood almost wholesale. But of all the machines,

including those which will cut the great draining-trenches as a knife goes through butter, much the most wonderful in power, if not in ingenuity, is the machine which is used for breaking up metal soils.

If we try to dig into some of the heather land of Dorset, we find little pockets of almost red or rusty soil, as hard as metal. They are, indeed, pockets of iron, which is a part of the composition of all soils. In some parts of America this iron is so general and so stubborn that until lately no one had dreamt of destroying his tools in unequal contest; when iron meets iron, then comes the tug-of-war.

But this tug-of-war has now been won by the combined action of steam and steel; and machines have been made which will go through these iron soils at least as easily as our little humble ploughs go through the heavy clay soils of our Midland Counties. They will, if need be, dig trenches.

They are, of course, chiefly used in continents where spaces are broad, and where the so-called fields are not divided by our trim hedgerows. But there is some room for their use in Great Britain. The Germans, as we have seen, have recently brought very large areas into cultivation, partly with the aid of such powerful cultivators, partly by scientific knowledge on the subject of making soils. England, too, has barren areas, covered with a little heather or gorse and a few fir-trees, which might well produce plentiful crops if they were treated as these barren spaces in North Germany were treated.

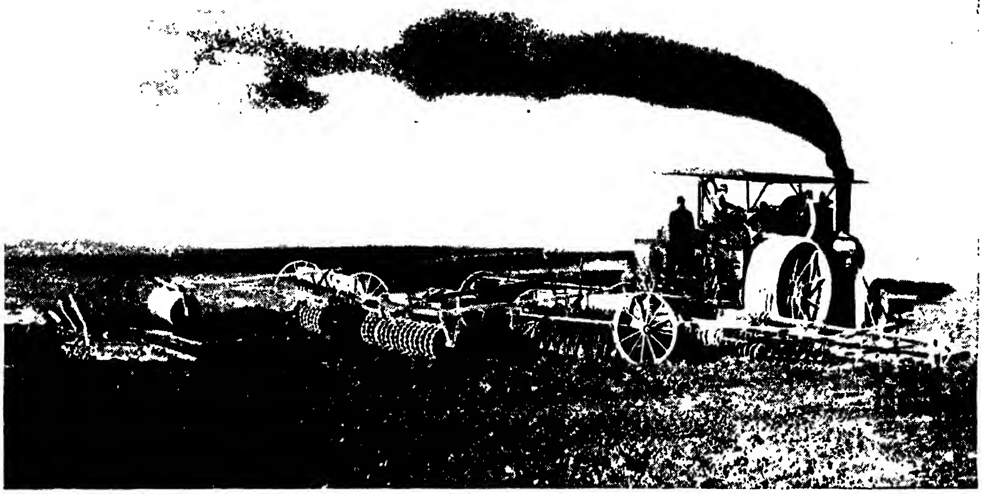
One further advantage of the steam plough over the horse-drawn plough is that the ground is not trampled into hard lumps by the horses' hoofs. The time is perhaps coming when motor-drawn ploughs and cultivators will be used. At present most of the best machines are pulled by a wire rope, coiling round a drum, by engines situated at either end of the space. The agricultural motor, too, is already used here and there, but there is not as yet any sign that it is doing away with the horse. Indeed, in England to-day, heavy horses, especially our grand shire horses, are more numerous and better in quality than they have ever been in history. It will be many years before we shall cease to see that most impressive of all forms of human labour, the grand line of horses leaning to the weight of the plough while the man, intent on the straight furrow, bears his weight now on this handle now on that. What glorious pictures, from primitive times up till to-day, have been drawn and painted of this primal service, the service which makes life possible for all mankind!

HAULING A PLOUGH BY MOTOR MACHINERY
The Ivel agricultural motor at work in England.

We read in the book of Genesis of the simple and easy life of the first man and woman "in their salad days." We read how, later, thorns and briars drove them to labour. It is a parallel worth attention, and it has not previously been drawn, that a somewhat similar succession of events is taking place in the corn Edens of the world. Professor Robertson, head, for many years, of the greatest agricultural college and training ground ever known even on the American continent, said that the great problem which had to be faced in the North-West of Canada was—weeds.

At first the virgin soil produced only such greens as were deliberately put into it. But, as time went on, the seeds of many weeds were gradually dropped; and they have so flourished that some parts even of the richest soils can scarcely be cultivated. In that forcing climate the weeds spring up in such vigour that they choke the wheat, and cannot be dealt with for fear of injuring the wheat.

This difficulty, too, can best be overcome by devices of cultivation. That popular crop, of which much has been heard in recent years, known as sugar-beet, needs forms of cultivation which absolutely destroy weeds. On many French farms one may scarcely find a weed, so effectively have the



PLOUGHING, HARROWING, AND ROLLING LAND AT THE SAME TIME

plots been cultivated and so good an opportunity of cleaning the ground is given by the date of the crop. Some such crops will have to be grown in Canada; and the Americans are peculiarly quick in adopting new tools and machines for performing all the requisite purposes—for ridging or harrowing, or pulling twitch or digging potatoes.

So far as cultivation goes, and the draining of the soil, we could now almost do without that first ploughman the worm, but he has no rival, no substitute but bacteria for blackening the soil and making it "kindly."

As one sees some of these modern giant machines in America, which can cut a drain through a bog at one passage, or scatter the opposition of iron itself, one is almost inclined to believe that modern machinery may perform the work of the centuries which have rubbed the primeval rocks into fertile earth. But when all is known, every result of this operation would be barren were not invisible agencies at work in the clods of some of the minutest things known to science, working hand in hand with these mechanical Behemoths.

BREAKING UP THE SUBSOIL BY EXPLOSIONS OF DYNAMITE

Cartridges of dynamite sunk into the soil and fired by electricity are being employed to-day in America for the purpose of clearing away stumps and boulders, making holes for the planting of trees, and generally breaking up the deep and valuable subsoil.

KINDRED GIANTS OF TWO CONTINENTS

A LORD OF THE DARK CONTINENT—THE AFRICAN ELEPHANT

MAN'S BIGGEST ALLY IN THE ANIMAL WORLD—THE INDIAN ELEPHANT

African elephants are not tamed except for menageries, but in India the elephant is an indispensable motive-power. The contrast in the shape of the head is a notable distinction between the two species.

THE AMAZING GIANTS

The Life and Characteristics of the Mighty Animals—the Elephant, the Rhinoceros, the Hippopotamus, and the Giraffe

SURVIVALS OF THE AGE OF MONSTERS

THE elephant, the rhinoceros, the hippopotamus, and one or two other weird-looking survivors from past ages help us to believe the almost incredible record of the rocks. Without these mighty beasts as evidence of the prodigal hand with which Nature piles bulk on bulk and adds strength to strength, we might hesitate to believe the story of the giants with which the earth in its twilight was peopled. But these colossal mammals are all unwittingly recorders, animate analogies, whose suggestive testimony is not to be overborne.

In the twentieth century Asia and Africa possess animals strangely fantastic in design and unwieldy in bulk like those of distant ages. They enable us in imagination to clothe with flesh and invest with action and intelligence the mighty bones which we blast or dig from the stony matrix in which they were interred long before the creature who became man had attained to human attributes or form.

The elephant remains the most impressive picture in the whole animal kingdom. He has about him a suggestion of the archaic; and as he stands, quiet and reflective, at his ease, he suggests some mighty figure carved from a rock rather than a thing of flesh and blood.

The elephant is one of the rare instances in Nature in which development of bulk has been accompanied by development of brain. It is to that phenomenon that we owe the persistence of the species. On the other hand, the rhinoceros and the hippopotamus have survived without high mental development, and the same holds good of puny insectivorous animals, and of degenerate types such as the sloths.

But there is a great difference between elephants and the other ungulates on the one hand, and the more primitive types on the other. The hippopotamus and the rhinoceros have been favoured by their surroundings. They have not had to endure excessive competition. The insectivores have adapted themselves, in common with other animals of lowly type, to life underground or in the trees, or to night prowling in search of food easily obtained without contests with other animals.

But the elephant is not fitted for a semi-aquatic life such as that which the hippopotamus leads; it cannot burrow like the animals that make their home underground; it cannot take to the trees. It has had to make the best of life in the open or in the jungle. The fact that in past ages it spread far and wide over the earth shows that adaptability was not lacking in the early elephant forms. The mammoth, which was a cousin of the Indian elephant, roamed from England to Behring Strait, whence it penetrated into America. It was woolly and hairy, and thus suited to the cold climates which it inhabited. It was contemporary with primæval man; its flesh helped to feed him; its hide may have made him whips and such harness as he employed; its ivory was his drawing-board, and we owe to the sketches on mammoth tusks our knowledge of the fact that he and the mammoth were rival claimants to the earth.

Geologically speaking, the mammoth ceased to exist but yesterday. Entire carcases have been found embedded in the soil of Siberia and Russia, an exceptional thaw melting the frozen mud in which they had been for ages enveloped. Dean Buckland made his guests partake of flesh from a mammoth which came to light in his day, redeemed from the marsh in which it had been frozen after sinking hundreds of thousands of years before. A century ago one was discovered near the mouth of the Lena, entire, with its brain uninjured,

its eyes still staring from the head, with flesh and hair and internal organs intact, with its last meal of young shoots of pine and fir and cones undigested in its stomach. Siberia is a mortuary of mammoths, which has exported enormous quantities of ivory derived from this source. Indeed, it has been stated that certain islands of Siberia are simply heaps of mammoth bones.

The Dwindling in Size of the Elephant Family when Ill Fed

The mammoth, the mastodon, and the dinotherium were the commonest of the varieties into which the elephant family developed, but to-day only the African and Indian elephants remain. Mammoths measuring 13 ft. in height have been found, but the average seems to have been a good deal smaller than that of present-day elephants. The average was about 3 ft. less than the figure mentioned. Hence the mammoth was of slighter proportions than some members of the elephant group which have existed. The Narbadda elephant of India, for example, is known to have measured at least 16 ft. in height, which is quite 4 ft. more than the largest known of modern elephants. But there were many sizes of proboscideans, from the Narbadda giants down to pigmy elephants, no bigger than Shetland ponies, which frequented Malta, Cyprus, and some of the neighbouring islands in pleistocene times. These latter, however, were the result of degeneration; they were the descendants of bigger elephants, and gradually became dwarfed in accordance with the limited area at their disposal. It is difficult to account for the disappearance of the mammoth and the mastodon, seeing that such magnificent animals have survived in Africa and Asia. Change of climate, we must suppose, was primarily responsible. But the Indian elephant, like the tiger, seems to have descended from stock which had become habituated to a cold temperature.

Is the Elephant Most at Home in Hot or Cold Countries?

Young elephants are born thickly covered with hair, as were the mammoths, and the species is very intolerant of heat, seeking shelter throughout the hottest part of the day, and taking baths to cool itself, even adding to its defence against the sun an artificial thatch for its back.

The African elephant, on the contrary, appears to revel in the heat of a tropical sun, and is active throughout the day. It is not impossible that disease resulting from parasitic organisms had something to do with the disappearance of the mighty hosts of trunk-bearing animals which once roamed the earth. The human race is smitten from time to time by plagues which sleep for hundreds of years; and it is not unreasonable to suppose that the disappearance of so many of the great animals of the past may have been due in some measure to a corresponding cause.

Be that as it may, the tuskers of India and Africa remain to remind us that not all of Nature's wonders are extinct. The boast would not hold good for long—at any rate, so far as Africa is concerned—were it not for legislative action. The slaughter of African elephants has been one of the scandals of latter-day civilisation. For years the ivory imported into Belgium represented the destruction of 18,000 elephants a year. The death-roll was monstrous in British territory, too, until the other year, when regulations were issued prohibiting the slaughter of these noble beasts except under specific authority.

How the Intelligence of the Elephant has Grown with Its Trunk

Thanks to a great find of remains in Egypt, the ancestry of the elephant has now been clearly traced; and Mr. Kipling's playful theory as to the origin of the trunk will no longer satisfy even nursery students of natural history. We cannot within the limits of this chapter trace the whole story of the elephant's equipment, but the important fact is that we have got the clue to the origin of the trunk. That is the implement which has helped the elephant to develop his intelligence, just as his hand helped man. The elephant's trunk is, next to the hand of the primate, perhaps the most wonderful natural implement in Nature, though we must be careful not to overlook the bill of the bird, and the mandibles of the bees and ants.

But undoubtedly the trunk has given the elephant extraordinary power. With it he smells, feeds, drinks; with it he can pick up a needle or a ponderous weight. In the Indian elephant it is a one-fingered instrument; in the African elephant it is two-fingered. Whence came this organ? It seems to have resulted from one of those experiments of Nature which strike us as freakish. It began first of all with an animal which produced the lower jaw into a long, trough-like chin. We may hazard a guess at the reason for this seeming malformation. The animal was developing in height; and as it was a browsing animal, it had either

to increase the length of its neck or find some other way of reaching the ground with its mouth. To have increased the amplitude of the neck would have been impossible, for so vast a head could not have been supported upon so slender a column as the neck must necessarily constitute. All the long-necked monsters of old time, it will be remembered, had what seem to us absurdly small heads; they had no room for brains, and so they died out. But the elephant produced this long lower jaw.

Obviously, then, the upper part must have some correspondence. The result was jaw was therefore shortened, and the trunk became the means of getting food, aided by two massive incisor teeth which developed into tusks to act as instruments for digging, either for roots or in quest of water, and, secondarily, as weapons of offence and defence. This type became the most successful, and the earlier forms died out. To-day the trunk is the elephant's most important organ. An elephant without a trunk would be like a man without hands, for the proboscis is the elephant's hand. With it he picks his food, the tender shoots of trees, fruit, tussocks of grass, or whatever it be. Of course, it need not be said that

A CAPTURED HERD OF WILD ELEPHANTS CROSSING A RIVER IN SIAM

that, instead of adding new weight to the already ponderous head by extending the upper jaw, the nose and upper lip were gradually developed in advance of the upper jaw, and an examination of the lower side of the elephant's trunk to-day reveals the vestiges of the margins of the lip itself. From an exaggerated, pig-like snout the elephant fashioned a trunk, an organ which acquired the art of prehension. As the trunk increased in size, so the necessity for the long lower jav disappeared. The lower

the animal is exclusively herbivorous. In its wild state the Indian elephant seeks the shade during the day, and wanders feeding the greater part of the night. The African species is more a diurnal animal. The former averages 9 to 10 ft. in height, but animals measuring 12 ft. in height have been known. The average of the African species is probably higher and the bulk greater. Jumbo, the Zoological Gardens elephant, stood 11 ft. at the shoulder, and weighed $6\frac{1}{2}$ tons, but elephants of at

least 12 ft. in height have been reported from Abyssinia. Probably the biggest of the two species attain pretty much the same dimensions, but elephants of from 10 to 11 ft. would seem to be more common in Africa than in India. It is impossible to state how long an elephant lives, but, from observations made upon captive animals, it is computed that 150 years is a fair average. The survey of many skulls leads to the conclusion that there has been a steady, if slight, development of brain in the elephant.

What Critics of the Intelligence of Elephants Say Against Them

But here the student is apt to fall between two stools. There is a danger of his being led either into a too generous estimate of the elephant's natural intelligence, or, on the other hand, into taking sides with those who, on examination of the evidence, rate the animal's intelligence on an absurdly low scale.

The fact is that in dealing with elephants man has to start his training de novo with each animal, as is the case with the cheetah. Therefore to compare the elephant with the horse or the dog is to give an entirely false estimate of the mental powers of the larger animal. But even with all that may be said from this point of view, no animal in the world is more educable than the elephant. No naturalist denies that.

The work that elephants accomplish on public works in India, in the carrying and stacking of timber, and the placing in position of large masses of masonry in building operations—this, when all is said and done, eclipses the performance of any other animal. But while educability is conceded, the critic of the elephant complains that the animal has no originality, that it cannot deal with an unexpected situation, that it will never volunteer its services, but will let its master be assassinated before its eyes, that it will jeopardise his life by bolting before a tiger.

Has the Big Elephant More Wisdom than He is Credited With

This may be so. But is this quite a fair line of argument? Will every dog in a sudden crisis defend its master from a murderous attack? Will not some of them run whimpering away? And is man himself always staunch in the presence of a tiger, or in face of other sudden danger? Will not a Hindu servant see his master assassinated in his presence, or desert him when a tiger charges?

Undoubtedly the reputation of the elephant has suffered from his exclusion from the Durbar processions. He was no to be trusted, native authorities said the sound of firing might make him bolt, a sudden attack of temper might upset him Well, our long-educated horse never draws a Royal carriage in public procession in London without careful preliminary training over the identical route. He is constantly accustomed to the sight of fluttering flags, to the noise of bands and gunfire. Clearly there is no case here for the superior intelligence of the horse.

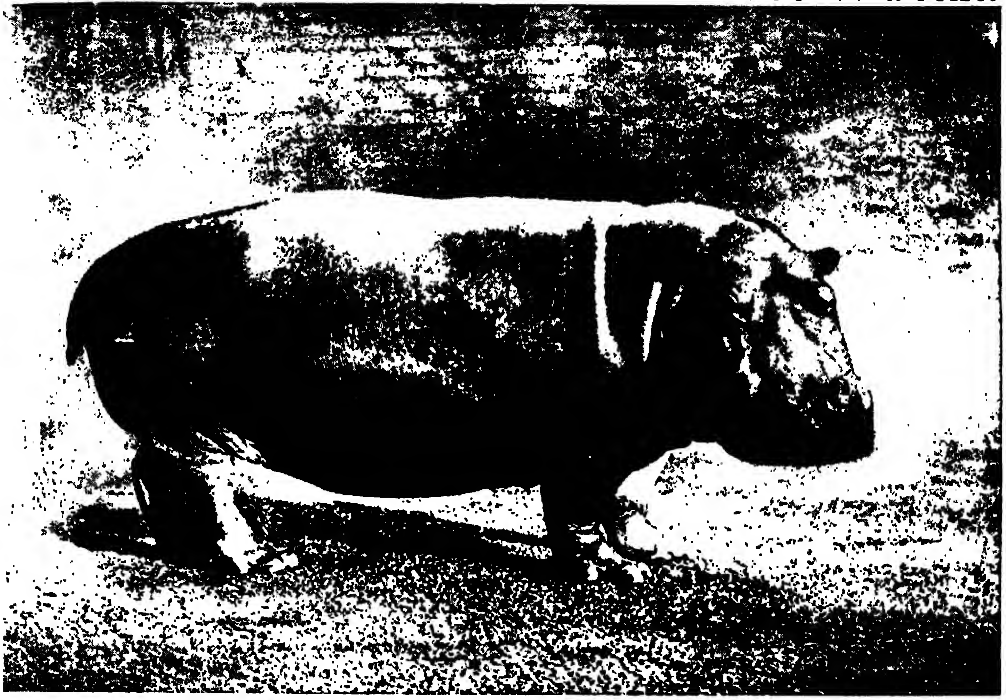
Elephants lift their riders, by means of the trunk, on to their backs, and they can pick up very minute objects with it. But they do not carry their loads by means of this implement. Baulks of timber are carried between the jaws, or balanced across the tusks; or a stout rope, to which the timber or stone is attached, is carried between the teeth. But they do use the trunk for testing their work; and the following little picture, from the pen of an Indian artillery officer, of a Government gun-elephant on duty, interestingly illustrates his methods.

How the Elephant Understands a Difficulty and Will Take Command of a Team

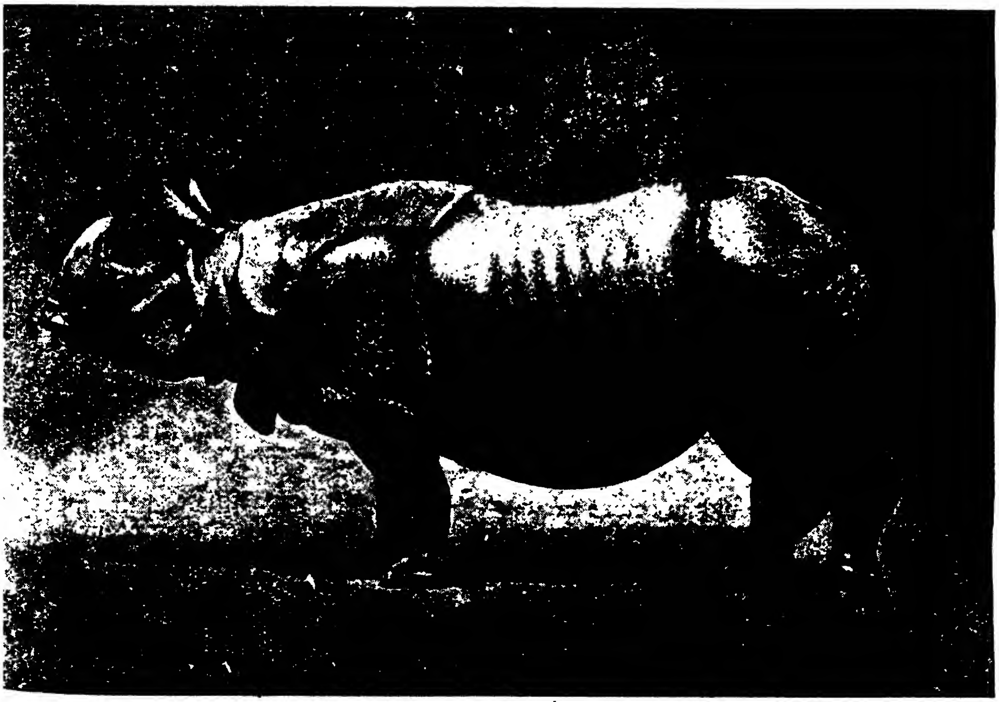
When a gun comes to grief, this experienced writer says, the elephant marches up with the important air of an experienced engineer, and deliberately inspects the state of affairs. Thrusting his trunk round a spoke of one wheel, he gives it a lift, as if to ascertain the depth and tenacity of the mud, then walks quietly round and does the same by the other wheel, dropping it again, with a funny twinkle of the eye, as if he said to himself: "All right; I can start her, I think." Then he deliberates for a few minutes, gives a slight push here and a slight push there, when, having at last made up his mind as to the best mode of proceeding, he probably applies his forehead (previously padded) to the muzzle of the gun, and, uttering a shrill, trumpet-like sound, as a signal for the gun-bullocks to pull together, pushes against it with all his weight, while the bullocks obey the signal and pull away too. This generally starts the gun. But if the bullocks are sulky, and refuse to obey the signal, the elephant gets perfectly furious, and rushes at them, branidshing his trunk with such ferocity as usually to compel obedience.

The elephant approaches the human in his affections and in his hatreds, and there exists between him and his master perhaps a better understanding than between man and any other animal. The combination between a shepherd and his dog is wonderful,

\MAZING SURVIVALS OF THE EARLY WORLD



THE HIPPOPOTAMUS, THE BIGGEST LAND MAMMAL AFTER THE ELEPHANT



THE RHINOCEROS, A RELIC OF AN ERA OF ARMOUR

't intelligence, but a sort of unsplendid isolation has kept the hippopotamus among the survivors the past. The rhinoceros owes his continued existence to an effective armour coupled with moderate mobility, displayed in almost inaccessible wilds.

but no dog ever held its puppy to be operated upon by its master. That has been done by an elephant, the dam deliberately pinning down her calf to allow her master to operate upon a wound which the youngster had contracted. No animal but the elephant makes a real tool. The elephant picks a branch, strips it of all but its topmost plume of leaves, and uses this as a fan to brush away flies. Moreover, it will pull up a stake and use it as a scraper for the removal of the leeches with which it is at times attacked.

The Elephant Capable of Independent Judgment Without Orders from His Master

Even the rogue elephant, a pariah expelled from his herd, shows extraordinary intelligence. Only on the rarest occasions does the male elephant make an unprovoked attack upon man. But a rogue will. Rogues have been known to hold up a road, and even to stop a line of railway. One, whose doings Sir E. Tennant recorded, "treed" a couple of men in a Ceylon plantation. First it tried to uproot the tree, then to butt it over. This failing, it went to a stack of timber some distance away, and removed it all, thirty-six pieces, one at a time, to the root of the tree. Placing himself on this pile, the elephant stretched out his trunk and tried to reach his prey, but was shot dead for his pains.

Surely these instances go to prove that the elephant is not a mere automaton; that it can originate; that it is not dependent wholly upon the order of its master. The elephant which, finding a drinking-trough useless through the support at one end having fallen, restored the horizontal by replacing the fallen prop in position, did so without instruction. That was a new problem to the elephant, met by its own sagacity. The wisdom of the elephant may not equal all that the animal's greatest admirers fondly assert, but it is certainly higher than the opposite school of naturalists would have us believe.

The Usefulness of the Enormous Appetite of the Gigantic River-hog

If those who take a middle course err on the side of an over-generous estimate, they may gladly do so in company with Sir Ray Lankester, who regards the elephant as the most intelligent and lovable of animals.

The elephant, then, has earned the place that he retains in the world. What are we to say of the hippopotamus? High intelligence cannot be pleaded for this great river-pig. The biggest of land animals, next to the elephant, measuring as much as fifteen feet in length and weighing some four or five tons, he has always presented a fair mark for the dart of time. He has survived because of his perfect adaptation to a singularly favourable habitat. His habit is to keep to the river by day, and to go ashore at night. He is as much at home in the water as on dry land. He is well fitted for an aquatic life, for, with ears and nostrels hermetically sealed at will, he sinks to the bottom of the water, and can run along the river-bed with almost as great facility as upon the land. He needs to rise to the surface only once in five or ten minutes to breathe, and all day long he can browse upon the rich vegetation which the river bed and banks afford. At night, when all is still, he roams afield, there to supplement the diet which his hunt by day has afforded. He is endowed with an enormous appetite: his stomach holds between five and six bushels, and this appetite has been productive of substantial advantage to man. The river-hog's hunger has impelled him to eat voraciously of the river growths; and by his destruction of such vegetation in the waterways he has helped to keep rivers in their beds which must otherwise have become choked and have flooded areas far and wide.

The Hippopotamus which Eats Too Much to be Allowed to Range the World at Large

But the range of the hippopotamus today is very limited, and the genus is doomed. So long as the White Nile and other rivers clothe their banks with dense masses of reeds impervious to man, the beast is safe, but where a river bank comes within the borders of cultivated land, the river-hog must go: it levies too heavy a toll upon crops to be tolerated. So, little by little, its world, limited now entirely to Africa, becomes more and more restricted; and the time must come when these animals, if alive at all, will be known only to zoological gardens. It is sad, but inevitable.

Once the hippopotamus ranged all over Europe, as far south as Italy, and as far north as England. Right away up to Yorkshire, remains of the ancient hippopotamus are found; and as they occur in company with relics of the reindeer, naturalists are presented with a pretty little puzzle which they have not been able to solve. One theory is that the hippopotamus ranged north in the summer and returned south in the winter. This, however, postulates an activity and zest for travel to which all existing hippopotamuses are strangers. Nowadays they never stray far from their

homes. They travel to and from the river by well-marked paths. Should heavy rain fall while they are absent from the river, they are lost, for the downfall washes away the scent by which alone they are able to find their way.

In general structure the hippopotamus has kept pretty much to a generalised design, yet he has decidedly helpful features. The forward protruding tusks of the lower jaw are admirably suited for tearing up vegetation; the high-placed nostrils are a life-saving device. Where he is secure from the attacks of men, the hippopotamus is a noisy, frolicsome beast, coming up from the bottom of the river with a rare uproar. But where men hunt him, he is cautious, and, gently nosing his way up among the vegetation, he thrusts only his nostrils into the air, and breathes as noiselessly as a slumbering infant.

It is rather tragic that the devoted mother hippopotamus is the animal most in danger. She rises frequently to the surface to enable her calf to breathe. The little one stands upon her neck, and she must rise high and advertise her presence, so making herself a good mark for the man with a gun. Navigators who make their way up rivers in small boats do not love the hippopotamus. It frequently shows a great aversion to boats, and not the stoutest-built craft is safe from it should it make up its mind to attack, as in all likelihood it will, once it sights the boat.

There is a smaller species of hippopotamus than the one we have been considering. This is a Liberian representative, a pigmy version of the other, whose habits resemble those of a big wild pig with a special fondness for water.

THE TALLEST ANIMAL ALIVE

The maximum height of the giraffe is supposed to be about 18 feet, but the animal has a long, extensible tongue and prehensile lips, and can gather its food from almost incredibly lofty trees.

The rhinoceros has not been favoured to such an extent as the hippopotamus in the matter of habitat, but its almost impenetrable hide, its horn or horns, and its immense strength have sufficed to keep it still among the living animals of the world. But innumerable species, which had the whole of Europe as well as great part of Asia and America for their home, have become extinct. Central England and Wales had the slender-nosed rhinoceros; southern England and South Wales had the big-nosed variety, while practically the whole of England and Wales teemed with the woolly rhinoceros down to the time of neolithic man. At present the rhinoceros is confined to the continent of Africa and the south-eastern part of Asia. Although it revels in a mud bath, the rhinoceros is essentially a land animal, feeding on grass and the young shoots of trees. Although in weight it may not equal the hippopotamus, the height of the biggest of the genus — well over six feet at the shoulder—is nearly twice that of the other animal. Therefore, in size, though not in bulk, it ranks next to the elephant.

The habits of these animals, wherever they may be found, vary very little. During the day they rest, unless disturbed, in high grass or thorn bushes, and feed at night. They have poor eyesight, like the elephant, but their ability to detect the scent of an enemy, and especially that of man, is acute. Ordinarily they will amble

away if challenged, quickening their pace, if pursued, into an ungainly gallop, sufficient to carry them beyond the reach of a man unless he be reasonably well mounted. If, however, they are suddenly confronted and see no way of escape, they will charge with great impetuosity, and either gore with their terrible horn or ply the formidable tusks with which the lower jaw is furnished.

The Friendly Bird-sentinel that Warns the Ungainly Rhinoceros

With its massive armour-plating the adult rhinoceros has not much to fear from animal attacks. So far as we know, there has been nothing to account for its extermination but change of climate in geological times, and, within historic times, the advance of civilisation upon its preserves. It is interesting to note that this huge beast depends for its safety to a certain extent upon one of those curious associations which we find in Nature. The preserver of the rhinoceros is a bird, the rhinoceros bird, which, hovering about the animal in quest of insects, not only conduces to the comfort of the brute by relieving it of parasites, but contributes to its safety by the loud screeches and flapping of wings with which it acclaims the advent of a foe in the shape of man. This habit of the bird at once gives the rhinoceros the signal, when it bolts. The value of such an association is obvious, for a man might steal upwind unobserved close to a rhinoceros, were it not for the warning afforded by the feathered sentry. The rhinoceros is among the animals doomed, but his fate must have been sealed earlier had it not been for his winged ally.

The Animal in which Everything Else is Subordinated to Height

And now, although to do so is to fly in the face of all conventional classification—as indeed the whole grouping of this chapter does—we pass to a very different type of giant, and one of the strangest, the giraffe, another of the animals in whose existence we should flatly refuse to believe if our eyes could not see him. He must be considered in a chapter on giants, for he is the tallest of living animals. With a height averaging over fifteen feet for the males, and from thirteen to fourteen feet for the females, the giraffe frequently exceeds sixteen feet, sometimes reaching eighteen feet.

Here, then, is an animal which seems to have applied to itself the homely phrase that there is always room at the top. For the giraffe depends for its food upon the high-growing foliage of trees, the acacia in particular. To reach its food it has had to develop on lines which have no exact parallel, though, thanks in the main to Sir Harry Johnston, we now know of the mysterious okapi, which furnishes the connecting link between the giraffidæ and many extinct forms. Everything has been done to give the giraffe height. Merely long legs do not suffice; the front pair must be higher than the hind pair in order to thrust up the neck where it joins the sloping trunk. The neck itself, though containing but the usual seven vertebræ common to all mammals, is enormously elongated, and the head can be placed in a line with the neck, so as still further to extend the reach, while the tongue is a marvel of extensibility and prehension.

The giraffe is one of the most specialised of animals, and should his tree-fare fail him he would be desperately pressed, for ground-feeding is a matter of extreme difficulty, necessitating his straddling wide with his front legs in order to bring his mouth to the earth. With his flexible prehensile lips, and a tongue whose tip can be thrust into the ring of a small latchkey, the giraffe is admirably fitted for plucking the leaves of trees and avoiding their thorns.

How Long can the Giraffe Live in the Desert Without Drinking?

But he is a puzzle to zoologists, in that he is better qualified than any other mammal to withstand thirst. Restricted now to Africa south of the Sahara, these animals are found in the desert of Kalahari, where it is believed they cannot drink for seven or eight months of the year. Indeed, they are reputed by the natives never to drink at all. Animals can in course of time dispense with drink—the tame rabbit, in the hands of thoughtless people, never gets any moisture save that which it derives from green food—and the giraffe may be able to dispense with liquid for this great time. But there is always the possibility that desert animals know of water supplies of which men are ignorant, and the Kalahari giraffe's abstention from water may be less prolonged than is supposed.

In habits this giant is the most inoffensive of creatures. Its horns are valueless for offence or defence. Its sole weapons are its hind feet. With these it can kick with vast force and with such speed that the action of the leg cannot be followed by the eye. The lion is, next to merciless man, the giraffe's most terrible enemy. In a fair run the giraffe would beat the lion for

speed, but with his head in the clouds, or, at any rate, in the foliage, he can easily be stalked. Giraffes have been shot which bore old wounds caused by a lion's claws, showing that sometimes the herbivore escapes. That is not often the case, however, once the lion strikes. His teeth are driven through the giraffe's neck, and all is over.

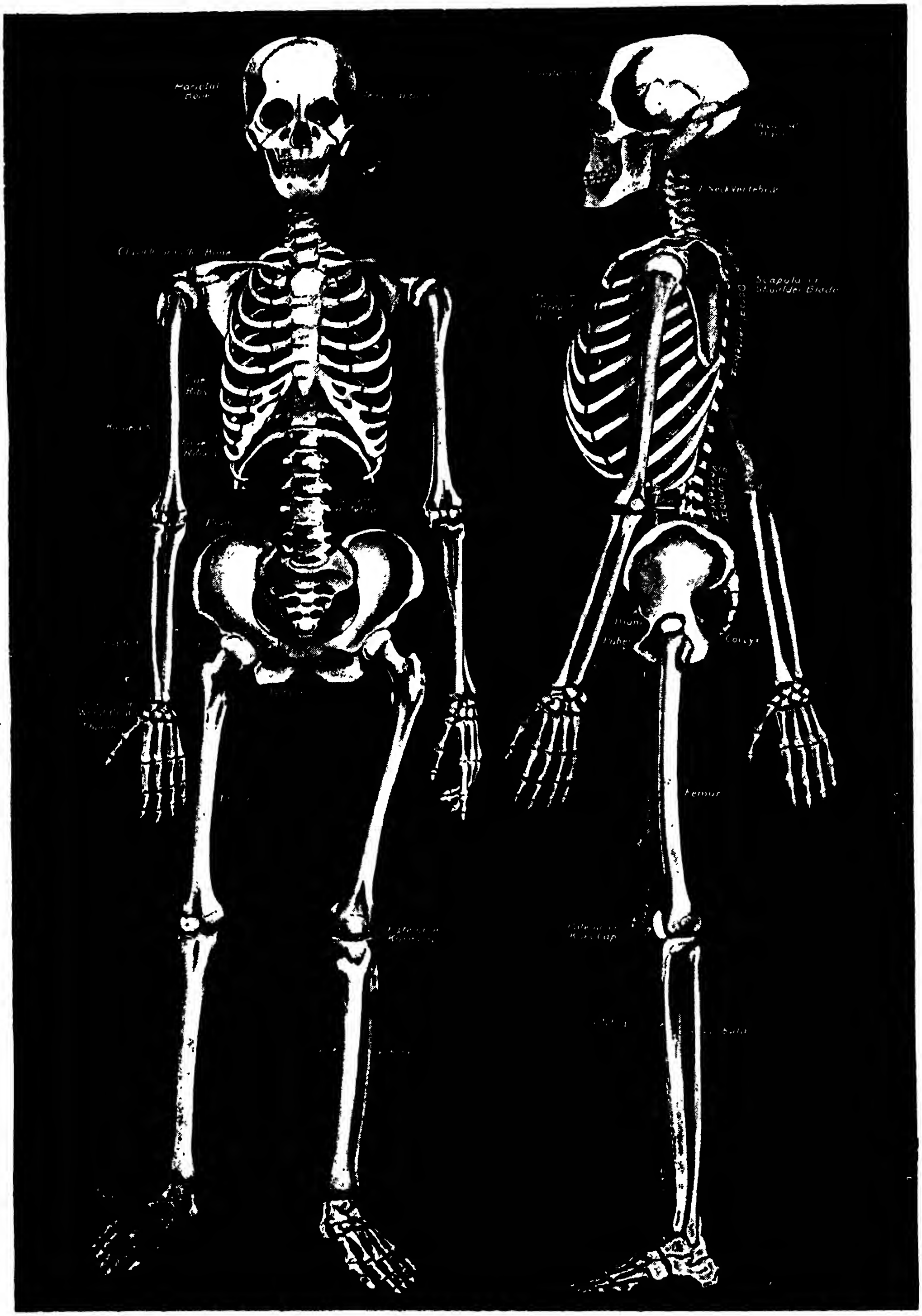
We have known the giraffe in England for nearly a century, otherwise he would be an incredible beast. As it is, he is one of the strangest-looking animals in existence.

All the giants in this chapter, with the exception, it may be, of the useful Indian elephant, are doomed to extinction. It is of interest, then, to group them in one section, and derive, from a brief glance at their characteristics, some little inkling as to what were the habits and appearance of old-time monsters which they have succeeded, though the world, when those creatures held sway, was so different from ours that imagination cannot place them with certainty in their true surroundings.

THE MOUTH OF A HIPPOPOTAMUS

Only a whale can rival the hippopotamus in mouth-capacity, as may be understood from the gape of this monster. This photograph and those on page 815 are by Mr. Gambier Bolton, and are reproduced here by permission of the Autotype Fine Art Company.

THE BONY SCAFFOLDING OF MAN'S BODY



This picture shows how the human frame is built up strongly for the protection of its vital organs, and plentifully hinged to admit of the free movements of the limbs in all directions.

MAN AND HIS SYSTEMS

The Marvellous Living House that Human Life Inhabits, and How It is Built Up

THE FRAMEWORK OF THE HUMAN BODY

FIRST it is necessary to get some idea of man's body as a whole—what it is, and why it is what it is. Thereafter we might begin at the surface and deal with the skin, and go on to study the deeper structures. Or we might take the various parts of the body in their turn, beginning, say, with the head, and then dealing with trunk and limbs.

To the anatomist, studying structure, and to the physiologist, studying function, neither of these methods is worth a moment's consideration, sensible and convenient though they seem. It is true that in the actual process of anatomy or dissection we must begin with the skin and the structures that lie just under it; but it does not follow that this method will suffice to give us any real understanding of the body. It is true, also, that for many purposes we require to study the head, the neck, the foot, and what not; and there is thus a "regional anatomy," which is the constant necessity and preoccupation of the surgeon who has to work in these regions, and must know exactly where he is, and what he may encounter at any moment. But apart from the business of dissection, and apart from the necessities of the surgeon, there is only one method of describing the body which is really worth anything. That is the method which depends upon the fact that the body is a combination of many "systems," each with its own structure and function.

This fact of "systems" is what we encounter when we look at the body of man—not as a whole, as we have lately done—but in its parts. We find that though, when we cut it, we may distinguish different layers, and though, when we seek to dismember it, it comes apart in obvious ways—head, trunk, limbs—yet it is built, not on the principle of layers, nor on the principle of repeated sections, like the joints of a centipede or a drain-pipe, but on the principle of systems.

It has a bony system, made of a special kind of tissue, for a special purpose, and found in special places. It has a muscular system, equally distinct and characteristic. Each of these systems is found in all parts of the body. But if we are wise, we shall think of, for instance, the bony system as all one, even though we find parts of it under the scalp and other parts inside our toes. This idea of systems works equally well from the point of structure, and from the point of function, too. Bone is bone, muscle is muscle everywhere, if studied under the microscope for their structure; and the physiologist reports that bone everywhere supports and muscle everywhere contracts.

Better still, this idea of systems is not only convenient when we are taking the body to pieces, and finding how it works, but it is the only method of study worth naming from the point of view of the life of man in the world. We think of him as a living being with an animal body, air-breathing, food-needing, and so forth, like all other living beings in many things, unique in many more. And we find systems to correspond. An animal that has to find food, and get about, has a bony system and a muscular system, and a system of joints for locomotion. An animal that has to digest food or aliment and absorb it has an alimentary system. For excreting, or ridding himself of his poisons, man has an excretory system. For producing necessary chemicals, he has a glandular system; for breathing, he has a respiratory system; for the circulation of the blood, which serves all these purposes, he has a circulatory system; and for the life of every part, and for its own higher purposes, he has a nervous system.

This is the intelligent way, and the only intelligent way, of looking into and perceiving the body of man. It promotes and

facilitates every aspect of our study, and, unlike other methods, it avoids the just reproach that science, as Wordsworth said, too often "murders to dissect."

The body of man, therefore, is a complex, made by the combination and interaction of a number of systems, each of which has a definite relation to some definite need of life. If we ask what the needs of man's life are, in most general terms, the answer is that they are two, the preservation of himself and the perpetuation of his kind. Self-preservation is asserted to be the first law of his being, and reproduction the second. It is questionable whether the order should not be reversed, but it suffices to treat these two great needs as co-ordinate and equal. Finally, then, in the human body we discern a system which is, in a sense, in the body but not of it, a system which, unlike all the others, does not exist for the body—nay, the body largely, if not wholly, exists for it. This is the reproductive system, including the "germ-plasm," the racial or parental tissue, which we find in the marvellous "germ-cells" of which the next generation is formed, and from the like of which the body that cares for them was formed. This reproductive system must be named and thought of apart from all that we have mentioned, for it is unique in function and in origin, as the study of development shows, and it is also unique and converse in its relation to the other systems and the bodily whole.

VERTEBRATE AND INVERTEBRATE ANIMALS

The sections above of an animal with a backbone and an animal with a shell show how in the one case the bony structure is inside the softer parts, and in the other case outside. A similar difference appears in fruits, as in the plum and the nut.

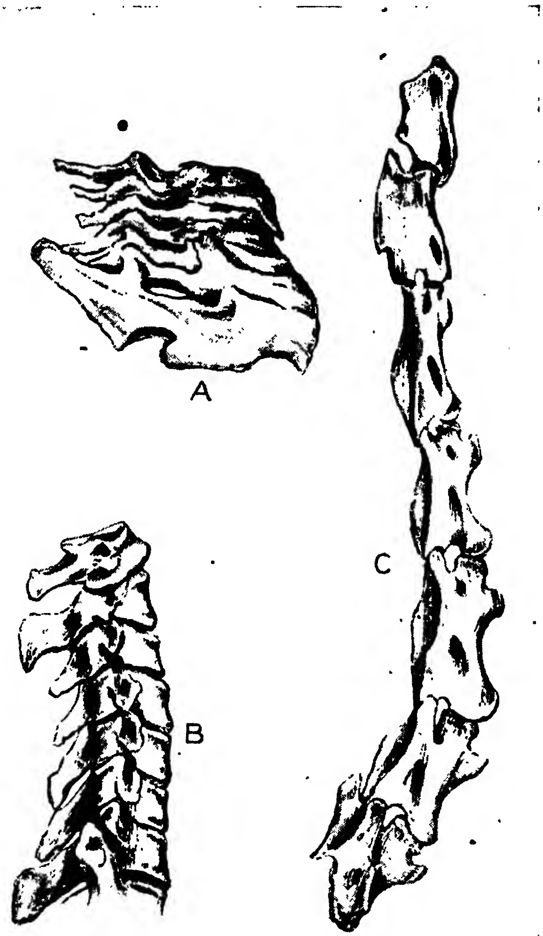
The first system to claim our attention is the bony or osseous system, the skeleton, which forms the more or less rigid framework of the body. It were almost preferable, if it were feasible, to take bones and muscles together, and think of them as the locomotor system, but this leads us on to take the nerves which order and control the muscles, and thus we learn how, though systems are many, the body is one. For practical purposes we must begin with the dry bones of anatomy, as every student does in our medical and anthropological schools.

If we look at the entire body we see that it is built on a plan of bilateral symmetry, having two halves, or sides, which are the same, yet not the same, as we learn on trying to fit a right hand into a left glove. This external symmetry is carried out by the arrangement of the trunk and head—the axial part of the body—and the limbs or appendages. The fact that there are two pairs of limbs, and also the fact that we find a succession of bony arches on each side, and a succession of knobs in the middle line of the back, suggest that the body is built not only in two-sided or bilateral symmetry, but also in the symmetry of a caterpillar, a railway line, or many other things which are formed by "repetition of parts." The question is momentous, because when we dive into the past we find that the remoter ancestors of the human body were so made. The worms, for instance, are built on this plan—a serial symmetry, depending on the repetition of a number of segments, each fundamentally the same as the others. Modify the front segment to be a sort of head, and the last to be a kind of tail, and we have what may be called the idea of a worm. Now, all backboned animals have certainly arisen from some such creature as a worm, built as a series of similar segments; and we cannot but scrutinise the body very closely for evidence of the same principle in its architecture.

The hint we gained from the repetition of the upper limbs and the lower limbs, and from the repetition of the ribs, and sections of the backbone, is undoubtedly a just one, and closer study only confirms it. If we study not only the adult but also the developing body, we find further evidence, for we discover a repetition of arches on each side of the neck, made of gristle or cartilage, which really correspond to the gill arches of the fish; and if we remember them as well as the series of ribs, coming out in pairs from no less than twelve sections of the backbone in succession, there can be no doubt at all that the pioneer evolutionists were right who

traced this fundamental architectural idea alike in man and in the worm. Nor can we confidently yet rebut the argument of theirs that, just as the front segment or segments of a worm may be modified to form its head, so the front—now the uppermost—segments of the backbone have been modified to form the skull. We shall think this daring and brilliant guess no less probable if we remember that the sections of the backbone are hollow, and form between them a long tube, which at its upper end expands to form the cavity of the skull; and that the brain and spinal cord, which are in all essentials one, are found inside the skull and the backbone respectively. This does, indeed, look as if the skull were made of expanded vertebræ, and suggests that even in the skull, which seems so unpromising for the purpose, there is evidence in favour of the argument that the body is really made from a number of similar sections, one in front of—or, in our case, above—the other.

We may keep this idea in mind when we study the skeleton, and we shall find nothing to contradict it when we make our first observation, which is that the whole framework of the body, and therefore the whole body itself, is all built around the backbone, which is itself not a single bone, but a long series of essentially similar bones. We must begin with the backbone for every reason, and think of it as the strong, central line, more important even than the keel of a ship, from which spring the ribs, like the ribs of a ship from its keel, and attached to which is the bony framework of all the rest of the body.



THE UNITY OF MAN AND ANIMALS

The bones in the neck of mammals number seven, whether they are thin plates as in the whale (A), elongated as in the giraffe (C), or compressed as in man (B).

Upon its top is nobly balanced the skull, the bony framework, and much more, of the head; much more, for the skull not only supports the muscles outside it, the face and jaws, but is also the brain-case, the protector of the "temple's inner shrine," where man himself resides.

At its tail end the backbone, instead of being continued indefinitely into a visible, external tail, "tails off" very suddenly into four small, degenerate, tail-vertebræ, fused together into a single bone, which is tucked and curved forwards, away from the outer world, instead of towards it, and is as conspicuously and notably humble, useless, degenerate, and degraded, even in size, as the head is lofty, useful, and highly evolved alike in structure and in proportions. He who would learn much of the history and destiny of man may contemplate and contrast the two extremities of his spinal column, with the unprecedented head at one end, and the shrivelled, degenerate skeleton of a vanished tail at the other.

For a considerable distance along the backbone, spine, or spinal or vertebral column—it has all these names—we see ribs projecting and curving outwards and then forwards and inwards until they meet or nearly meet in the front of the body, thus forming a kind of cage, box, or chest, as we call it, for a special purpose which requires that the walls of the body at this place

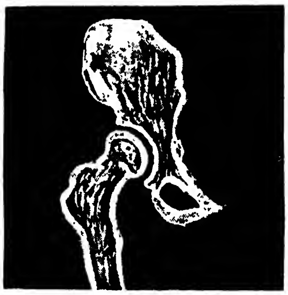
shall be more or less rigid. This is where the lungs are to lie, and they demand these ribs, together with the strong bone to which several pairs of them are attached in front—the breast-bone, or sternum.

Now we have reviewed the spine, with head and tail, and the ribs and breast-bone. What remains is scarcely less simple in principle. At a short distance along the spine, just after we pass the neck, we find an arrangement of bones forming more or less a girdle around the spine and the body, and this we call the shoulder-girdle, with its various parts, similar on the two sides of the body. Practically at the other end of the spine, just before we reach the curious little tail-vertebræ, we find a generally similar arrangement of bones, forming another girdle, which we call the pelvic-girdle, or pelvis, from the Latin word for a basin, since the pelvic-girdle is practically a spread-out basin of bone to hold the contents of the lower part of the body. There is so much general resemblance between shoulder-girdle and pelvic-girdle that we recall the idea of "repetition of parts."

That idea is remarkably borne out when we turn from the axial part of the body to its appendages, and note that each of these two girdles bears a pair of limbs. If one gets on all-fours and plays at "being a bear" one may lose human dignity, with the loss of the erect attitude; and it is notable how instinctively we all feel that we are making rather fools of ourselves when we go on all-fours. But we should at least think of ourselves in this position if we are to get a just idea of the build of the body and its framework. The whole architecture and scheme of the backbone and the head, the two girdles, and the two pairs of limbs in front and behind, will become clearer. Let us, then, think of ourselves erect, but try to study the erect body without forgetting what we learnt when we saw it horizontal. It was horizontal when its main lines were laid down.

In these few paragraphs we have actually outlined the human skeleton, the whole framework of the body. A few tiny bones may be found inside the ears, and the bones of the face and jaws must not be forgotten, but otherwise what has been said comprises the entire skeleton. One may easily spend a lifetime upon its study, and any number of lifetimes upon its comparative study in different races, and in man and the lower animals. But all the while we should have to remember the plain, simple, "common-sense" principles of its architecture, which were laid down for its ancestors in the water many million of years ago, and which have never been departed from, though such countless changes have been made, though the water has been left for the earth, and though the front part of the body has been permanently reared from the ground.

The backbone, so-called, is a series of small and very peculiar bones called vertebræ. Each vertebra is built on the same plan as the others; and if one compares the vertebra of the man, a mouse, and a mammoth, one finds that the essential features are similar in the vertebra which one can scarcely notice in one's hand, and the vertebra which one can scarcely lift. Not less noteworthy is the fact that all mammalian animals, with no more than two known exceptions, have the same number of vertebræ in the neck. We find seven vertebræ, neither more nor less, in the neck of a man, a giraffe, a whale, a bat, a buffalo. Evidently this backbone is altogether a very fundamental and old-established institution; and we must remember, when we study it in ourselves, that this is simply the human, as it might be the simian or the equine, backbone, and that very few of its features are peculiar to man at all.

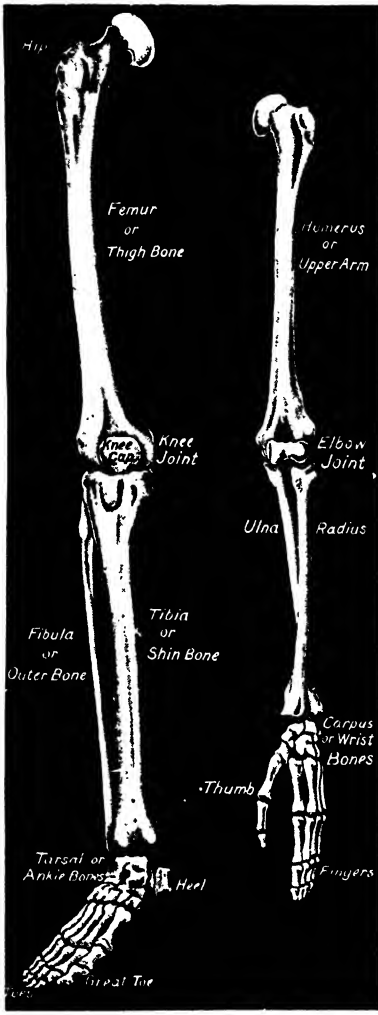


BALL-AND-SOCKET JOINT
This section of the hip-joint on the ball and cup principle shows the extreme pliability of the human body. It allows the leg to be moved in every direction and almost in a circle.

The topmost vertebra, the first of the seven in the neck, is called the atlas, for it supports the head; and this it does on two smooth surfaces, whose number is notable, for it distinguishes the mammalia from many other vertebrates, whose head is balanced at only one point on the atlas vertebra. The large and wide hole in the atlas, which is, indeed, scarcely more than a ring of bone, coincides with the great hole in the base of the skull, where the brain and the spinal cord are continuous with each other—or where, in other words, man changes the name, as he changes the name along what is really one street.

The first, or atlas, vertebra rests on the second, which is called the axis, as it well may be. It is as readily identifiable as the atlas itself for it has a great projection,

which fits into the atlas, and forms an axis of rotation whenever we turn our heads from side to side. Nothing can well be more important for man the erect than free movement of the head upon the neck. He must look up and down, and from side to side, in the interests, not only of sight, but also of hearing and smell. Sight, however, is so important that, in man above all, the eyeballs move wonderfully and freely together, not even the movement of the neck sufficing for their needs. But the facility with which the neck can be moved is truly marvellous. Whenever we move the head, for any purpose and in any direction, and note the ease and range and usefulness of this movement, we should remember the atlas and the axis vertebræ, to which between them, and to their remarkable modification for the purpose, we owe it all. Notable in many other animals, these movements are most notable in ourselves, and for our mode of life. In very young infants the strong fibres that prevent undue movement are not developed; and cases are known where an infant has been instantly killed in consequence of rough handling of the head and dislocation of these vertebræ. In hanging, death is due, as a rule, to dislocation and fracture in this neighbourhood, with consequent pressure upon, and destruction of, the spinal cord in this vital region. That is why a condemned man should be given a "drop"; and hanging which does not ensure this injury is gradual, brutal, and even uncertain.



THE BONES OF A MAN'S LIMBS

The bones in man's upper and lower limbs have a remarkable similarity in number and position. With one exception each bone in the leg is mated by one in the arm. The exception is the knee-cap, an extra bone not represented in the elbow, which needs freer movement.

The other five vertebræ of the neck are not particularly remarkable, except for their relation to each other, which is such as to give this part of the spinal column extreme mobility —evidently contrived to prevent us from being "stiff-necked." But we cannot leave such a notable and peculiar adaptation—*special* for a *general* purpose—as we find in these seven vertebræ, taken as a whole, and especially in the first two, without asking how it came about. If we are no longer to accept the view that they were made so, from nothing, and if we know that they have developed, somehow, from simple forms, we may well ask how such development occurred. Was it chance? Incredible! Was it in accord with some foreordained plan? An explanation which does not explain! Was it the result of long ages of natural selection, acting on random variations in the shape of the vertebræ, and gradually establishing the forms we see? This, the complete and orthodox Darwinian explanation, becomes yearly more difficult to believe, though it is doubtless part of the truth. What the whole truth may be, no one yet knows, and this is not even the place to discuss it. But we have met the first of not one, nor a dozen, nor a thousand, but of countless numbers of detailed facts of the body, of each one of which the same question must be asked; and of each one of similar facts, and different facts, in the bodies of all other living creatures. We are not fit to study the body of man, nor worthy to possess such a body, if we are to pass in succession by such amazing facts of structure, without at least asking ourselves how such things came to be. We are clever enough at using them, but we did not make them: they make us.

The next twelve vertebræ each have a pair of ribs jointed to them, and may readily be distinguished accordingly. The neck vertebræ were so inclined as to make a curve slightly convex forwards. The next

series, that bear the ribs, form the part of the spine which is concave forwards, thus increasing, of course, the capacity of the chest and the possible expansion of the lungs. Then follow five strong, large vertebræ, with no ribs attached, which make a marked and characteristic curve convex forwards, a curve which is largely responsible for that balance of the body whereby it stands erect. This forward convexity of the vertebræ in the small of the back, known as the lumbar vertebræ—compare the term "lumbago"—is somewhat more marked in women than in men. Otherwise the facts here noted are identical in the two sexes, as are all the essential facts of the skeleton, without exception. The bones of a woman are somewhat slighter, smaller, and smoother, on the average, simply in consequence of her less muscularity, but the difference of sex touches no essential feature. The number of ribs in both sexes is twenty-four; and there is no ground in anatomical fact for the view that, in accord with the ancient account of the Creation, man has one rib less than woman.

Parts that have Perished from Want of Use as Man has Risen in the Scale of Being

The next region of the backbone consists of five large vertebræ, fused together in the adult, to form one bone, which is called the sacrum, from the extraordinary superstition, once current, that it was the seat of the soul. The sides of the sacrum are connected with the pelvic-girdle, and thus with the lower limbs. Lastly, we find the tiny coccyx, the name of the bone, formed of four fused vertebræ, which is all that is left of the tail of man. This organ has some supply of nerves and blood-vessels, and even of muscles to move it, but it cannot be moved, much less wagged, and is as good an example of degeneracy of a structure no longer desirable as the body contains. The sacrum and the coccyx are curved concavely forwards; and this completes the list of such normal curves of the spine, as they easily seen and recognised in a side-view. To some extent we sit upon the sacrum and coccyx, but mainly upon the ischia, or sitting-bones, which are a specially developed part of the pelvic-girdle. This girdle is a complete one, meeting in front to complete that large bony ring in the middle of the pelvis, or basin, of which we know the sharp and well-marked outer and upper edges, just below our waist on either side.

The shoulder-girdle is much smaller and weaker than the pelvic-girdle, and much less completely deserves the name of a girdle at all. We are all familiar with the collar-bone, or clavicle, on each side, and with the shoulder-blade, or scapula.

On each side of the shoulder-girdle and the pelvic-girdle we find a cup-shaped hollow or socket, in which rests and moves the smooth, rounded head of a great bone. These are the two shoulder-joints and hip-joints, the two latter in especial being magnificent examples of what is called a ball-and-socket joint. And here we have reached the limbs.

The Duplication of Bones in the Upper and Lower Limbs

In accordance with the view that the upper and lower limbs are originally similar and illustrate the first plan of the body as a succession of repeated sections, we find that the skeleton of all the limbs is notably similar in plan. The upper arm has a single bone—the humerus—and the thigh has a single bone—the femur. Humerus and femur are jointed to the shoulder-girdle and the pelvic-girdle respectively by a joint of the same type. Upper and lower limbs, or arm and leg, as we must call them in the case of man, who uses them for such different purposes, are both alike in that the piece which is moulded on one bone is succeeded by a piece which is moulded on two—the humerus being jointed, at the elbow, to the radius and ulna, and the femur, at the knee, to the tibia and fibula. The knee and the elbow are thus naturally similar in the general principle of structure, and are essentially made for movement in one plane, unlike the ball-and-socket joints we have just seen. In each case, also, the skeleton of the limb breaks up from one large bone to two smaller ones.

The Need for the Knee-Cap Proved by the Unshielded Funny Bone of the Arm

When the hand lies with the palm forwards, the radius and the ulna lie parallel in the forearm, the radius being to the outer side. If, now, the hand be turned over, the lower end of the radius makes a kind of curved movement—with its centre at the elbow—from which the bone gets its name of radius; and its lower end now crosses over the ulna. It is part of the ulna that makes the projection at the back of the elbow, and it is a nerve, lying near the ulna, and known as the ulnar nerve that we excite when we say that we have hit our "funny bone." It is certainly a funny bone, for it is not a bone at all

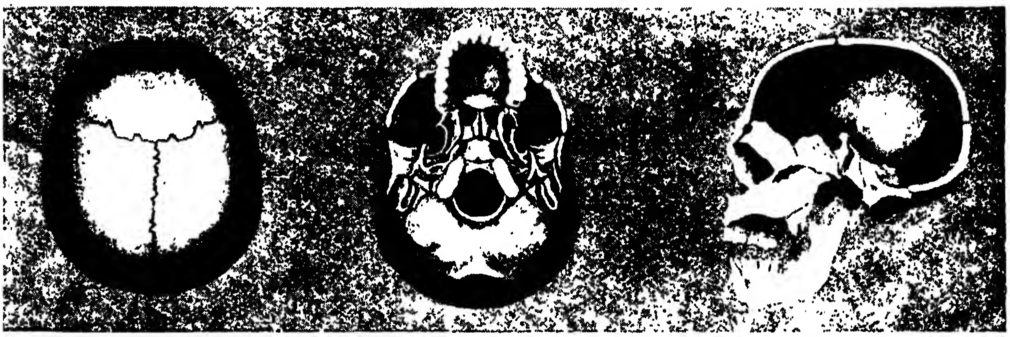
There might be a bone developed behind the elbow, in connection with the muscle that passes over the joint, but there is not.

The corresponding part of the knee is its front, and there we do find an extra bone developed to strengthen the great rope or tendon of the muscle which pulls over the front of the joint. This bone is the knee-cap, very interesting and useful, but not part of the essential scheme of the skeleton of the limb.

The tibia is the shin-bone, and the fibula, or clasp, lies on its outer side, forming a sort of clasp between ankle and knee. We can readily feel the head and the lower end of this bone, but the intervening part is well covered with muscle.

Again the limb breaks up, and the two bones of forearm or lower leg are succeeded at wrist and ankle by a number of small bones, of a wholly different shape. The and smaller bones for the one strong shaft with which the limb starts, is only to be understood intelligently, from the point of view of man as a whole, if we realise what it is that this limb is designed for, and what it is that it wishes to be capable of doing.

Of course, there are important differences in detail between the wrist and the ankle, for the ankle is largely modified to serve the peculiar attitude of man, and the wrist to serve the multiple uses of his hand. Obviously, there is nothing in the wrist to correspond to the large bone which forms the skeleton of the heel, nor to correspond with those features of the foot which help to form its mobile, strong, and delicate arch. But the group of bones at the wrist, and the group at the ankle, including those which form the skeleton of the back part of the foot, agree in presenting, towards the extremity of the limb, a surface for jointing



THREE VIEWS OF THE HUMAN SKULL, FROM THE TOP, FROM BELOW, AND IN SECTION

The upper part of the skull, or cranium, seems to be one large, hollow domed bone, but it is really three, that are loosely connected in infancy but are joined firmly together in later life. The base of the skull and front around the face are formed of strong, closely jointed bones, only one of which has a movement, and that is the lower jaw.

case is simplest in the wrist, where the two bones of the forearm yield to two rows of four small bones. The general plan of the ankle is similar. And now we may perceive what is the idea. The limb, which left the trunk in one big, strong piece, is gradually breaking itself up until it shall end in five separate pieces—our fingers and toes. This is the five-fingered arrangement of the limb of a vertebrate, which is to be found even in the frog, and which has so admirably served the life of so many billions of living creatures of a thousand kinds, from frog or frog-ancestors, up to man. We need not here insist upon the evident usefulness of this arrangement whereby the limb ends in fingers or toes—the toes, of course, decadent in ourselves, and thus not illustrative of the point. But we must insist that the anatomy of the limbs, the succession of joints, and the gradual substitution of more with a series of five small, long bones, built much after the fashion of the long bones seen higher up the limb, but now five in number, as compared with one or two. These are the metacarpals and metatarsals—the bones beyond the carpus (or wrist), and the tarsus (or corresponding part of the foot) respectively. They, in their turn, are jointed to series of similar bones, the skeleton of the fingers, of which three are found in each finger and toe, with the exception of the great toe and the thumb, which only have two. Here the skeleton of each limb ends; and we observe how the similarity of design, in general and in particular, which began with the ball-and-socket joint at shoulder and hip, is maintained to the detail of the small bones with which all the limbs end.

The skeleton of the head remains to consider. We recognise at once that the head

consists of two distinct parts—the skull, or cranium, and the face. They are close together, but they are plainly distinct; and one of the most marked features of human development is the small size of the face compared with the skull in a baby, and the great relative growth of the face in later years. The truth is that the skull contains the brain, and the brain presides over development, so that the development of the brain itself, in all but its highest parts, must be early. Hence the extraordinary relative size of the skull at birth.

Everywhere in the skeleton, so far, we have met movable joints, though we have [illegible]ooked at them closely. In the head, though we find numerous and complicated bones, we find only one movable joint on each side, that which joins the lower jaw to the skull, not counting the pair of joints between the head itself and the atlas vertebra. The upper jaw, for instance, has no movable joint with any other bone; and if we suppose that we can move it independently, as we can move the lower jaw, we are mistaken. We think we feel it moving, but that is a delusion. We cannot move the upper jaw without moving the whole skull.

The Widening Breach Between Man and Beast seen in His Facial Angle

The various bones of the face are concerned with its various functions, and thus comprise the jaws, in which we find the teeth, not bones, but somewhat allied to bones in some ways; and the bones of the nose, the cheeks, and the orbits, or hollows where the eyes lie and move. These bones are the framework of the face, and profoundly affect its appearance. Students of man have spent much time upon this question, especially in regard to the so-called "facial angle," which indicates the general shape of the face, and expresses, with some convenience, part of the difference between the face of a negro and that of a European man. But if we are to confine ourselves to what is not open to fallacy, we need say no more than that in the lower races of man the jaws protrude, whereas in higher races the front outline of the jaws is more vertical. These differences give us, respectively the prognathous and orthognathous types of face; and we find in them, perhaps, as notable differences between types of men as can be named—none the less so because the prognathous jaw is so evidently like the jaw of many animals, including the anthropoid apes, and thus increases the impression of lower physical type in the races and individuals who display it.

The skeleton of the skull consists of a number of strong, hard, compact bones, of very complicated form, which are firmly and rigidly jointed together to form the base of the skull; and of other bones which are stretched and expanded so as to hold the brain These latter bones, in the development of the individual, grow from membranes which they replace as they grow; and the points where the bony tissue first was laid down remain always more or less conspicuous.

The Nonsensical Inferences of Pseudo-Scientists who Judge by Outward Appearances

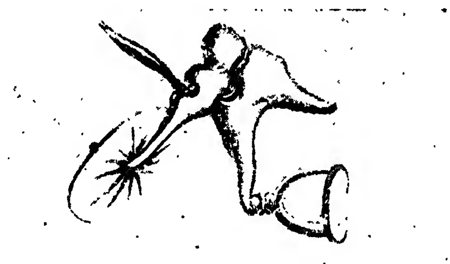
They furnish worthless and absurd indications to "phrenology"—a "science" which however, is not in all respects so foolish, as we shall later learn. The bones of the cranium are made of two plates, inner and outer, with looser bony tissue between; and sometimes this intervening part communicates with the outer world and is expanded to form an air space. These air spaces are also regarded with nonsensical concern by the phrenologist, who supposes them to indicate some special development of brain and corresponding fact of character. What he takes for brain is only air, however These air spaces are larger in men than women, and their development above a boy's eyes, at puberty, distinguishes this part of his skull from his sister's. In consequence, the skull of a man appears to recede more in the forehead region than the skull of a woman, the cause not being a defect in the male brain, but the addition of larger air spaces within the frontal bone

Such, in brief, is the skeleton or bony system of man. If we think of it as merely the framework of his body, we fall far short of the truth. It is that, but it is much more The rest of the body is moulded upon it But in one all-important respect it is almost like the skeleton of an invertebrate, which is outside its body, for the central nervous system, brain and spinal cord, are found inside the skeleton, in the skull and backbone

The Bone-Cells that, Working in the Dark, Build Up Our Framework

In this respect the skeleton is thus protective; and in the history of evolution has contrived to grow round, and outside and finally to enclose, the most precious parts of the nervous system. That is not nearly all. The skeleton is also made for locomotion. Its parts are jointed, and these joints, with the notable exception of those in the head, are movable. Thus, as the study of muscles and joints will show, this framework of the body serves also to move it as a whole from place to place, and to

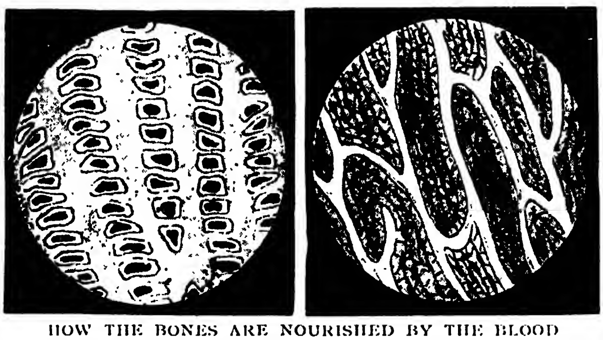
move its various portions in relation to other portions. Lastly, by an extraordinary device, we find that the interior of the long bones, such as the ribs and the various bones of the limbs, is filled with what we call bone marrow, and that this bone marrow by no means exists to nourish the bone, but is the great factory of the blood. Within our ribs and shins, from second to second, are being bred and fledged countless millions of red blood-cells, which compensate for the incessant death-rate of these short-lived units of the body of man.



THE SMALL BONES THAT HANG IN THE EAR

Between the drum of the outer ear and the drum of the inner ear three minute connected bones are stretched across the chamber of the middle ear. They are named the hammer, the anvil, and the stirrup, from their respective shapes.

This fact should suffice to remove the delusion that bone is a lifeless object, made once for all, and then left to serve a purely mechanical purpose. The minute anatomy of bone and of the bone marrow soon disproves that notion. And if anyone is disposed to think lightly of bone nevertheless, let him study the development of, say, the thigh-bone, or a bone of a finger, of a baby, and its gradual growth, in the same form, to many times its original proportions. This miracle actually happens, though it is all but incredible, and though not one man in a thousand has ever thought of it. The formation of such a bone is achieved originally by a number of cells whose nature it is, somehow, to produce bony tissue. They lay down, on a basis of cartilage, a rough outline of the future bone, like a sculptor's block of marble.



HOW THE BONES ARE NOURISHED BY THE BLOOD

A bone is often regarded as a lifeless object, made once for all and then left to serve a purely mechanical purpose. But a bone feeds, grows, and modifies its structure like any other living tissue. The picture on the right hand shows a magnified section of bone tissue, while that on the left shows a piece of ossifying cartilage.

Thereafter there appears a number of larger cells, which cannot make bone, but can destroy it. They play the part of the sculptor's chisel, and dissolve away the bone already made, in just such a fashion as to give it its characteristic shape, with a bulge here for one purpose, a ridge for another, a groove to hold a nerve, a hole to admit a blood-vessel to the interior of the bone, and so forth.

This these cells do, until the bone on which they work conforms to the ancient characters which similar bones display in all human beings, past and present. They are microscopic cells, and know nothing; they work in the dark, without overseer or plan or previous experience, and thus they do their work. The facts of sensation, much more the facts of memory and intelligence, are hard enough to fathom, but in some ways this everyday, unnoticed feat of the bone-chiselling cells, who wander about and dissolve a little here and a little more there, and so produce a thigh-bone or a shoulder-blade, which they never saw and know nothing of, beggars the understanding more utterly still. Modern science knows much, and can do much; it has observed the growth and construction of the bones, and found out the facts, only to find itself in the presence of a fact which leaves it gasping. It is remarkable that this most utterly insoluble of problems should have struck the imagination of the wise king to whose words the microscope of the embryologist only adds force: "As thou knowest not what is the way of the spirit, nor how the bones do grow in the womb of her that is with child, even so thou knowest not the works of God who maketh all." Evolution changes Solomon's terminology, but only makes his argument more pungent still. We can study the evolution of the bony skeleton from the earliest bony fishes up to ourselves. We can examine by the microscope and our coal-tar dyes "how the bones do grow" in the development of the individual, and even seem to make Solomon's argument obsolete. But the truth is as Spencer taught: the larger the sphere of knowledge, the larger its area of contact with the unknown.

THE HEALTHIEST KIND OF PLEASURE—A BATH IN THE SUNLIT SEA

It has been said that this picture of the bathers, by Mr. Henry Scott Tuke, A.R.A., conveys some conception of the feeling of exhilaration arising in the swimmer

SWIMMING AND HEALTH

The Art that Brings Us Back to Nature, with Sun and Air and Salt Water as Aids in our Cheerful Rite

WHO SHOULD BATHE & WHO SHOULD NOT

If we grant that water is useful outside the body, and if we analyse and summarise all the possible ways in which water may thus be useful, and if we carefully weigh the many methods of its application which man has invented, we find, in the upshot, that one thing alone, which man did not invent, meets all the indications, and that is the exercise and sport called swimming.

Normally and naturally we associate swimming with the open air. This is not to say that swimming in a covered bath is not well worth while. Its only superior as an exercise is swimming in the open air, and that is very high praise indeed. Much improvement has been wrought in this direction in recent years. Some day we shall have all children taught to swim. At present our attitude to the matter is to be learnt by anyone who will consider the population of London, and consult the Post Office Directory to see what is the provision of swimming baths for this huge population—one to hundreds of thousands. The writer's anxiety is here to do justice to covered swimming baths, while not underrating the superiority of open-air swimming, which we are about to consider. The covered bath has many advantages for the learner, it is invaluable in our climate during quite half the year, and there are many people who react so inadequately to cold water that their stay must be so brief as to prevent them from really getting any swimming exercise. For them, evidently, is the covered bath, the temperature of which they can, perhaps, comfortably stand for anything up to half an hour, and after which they will get a good reaction, though never the perfect reaction which comes from open-air swimming.

Open-air swimming may be in still salt water, still fresh water, streaming fresh water, or the sea. Open-air salt water baths, as also closed ones, have the advantage of the salt, which is real, but have the disadvantage that the water is still. The swimmer and the diver compensate for this by producing movement of their own, thus getting both the salt and the friction. River bathing has its virtues, and many a child may be safely taught to swim in a pleasant stream. Unfortunately, we are still far, in this country, from recognising that rivers were not made to carry drainage from any city or town on their banks to all that are lower down. When the great questions of the appreciation and conservation of natural resources come to their own, river pollution will be stopped, on many grounds, each quite sufficient in itself, and river bathing will be safe. Meanwhile, the hygienist thinks twice before he ventures into a river, and if he does, he probably prefers to spoil his swim rather than get any of the water into his nose or mouth, even for a moment.

No such objection obtains in the case of lakes or ponds whose source is known and which are kept free from pollution. Thus, though London is so deplorably ill-provided with swimming baths—as compared with, say, public-houses—at least it has the Serpentine, and there are few more satisfactory sights for the hygienist than to see hundreds of youngsters in the water together late on a summer afternoon, and crowds more hurrying to the spot and loosening collars and buttons as they go. The theory of parks as "lungs for London" really has a meaning when one sees them used in this fashion. Such opportunities should be made available wherever it is possible, and every encouragement should be afforded to parents and to children, by proper provision for safety and decency and by ready and cheap access on municipal trams and the like, for a form of health-

giving, body and nerve-developing exercise which may go far to counteract the many deteriorating influences of city life. In this connection the hygienist is bound to make a protest, on behalf of those who have neither voice nor influence. Something has been done for girls and women in recent years by the provision of facilities in swimming baths, and "mixed" or "family" bathing has been of value in allowing girls to be taught, for instance, by their own fathers, in whom they have confidence, and who might fear to entrust their daughters to the water otherwise. But so far as open-air bathing is concerned girls and women have much difficulty.

The scores and hundreds and thousands of those who bathed in the Serpentine in the wonderful summer of 1911 were all drawn from one sex; one-half of the race, the nation, its parents and the providers and its future, was wholly unrepresented. This is hard on individuals, and it is very hard on the nation, and especially on the physique of Londoners in this and coming generations. The defect, so evidently grave, could easily be remedied, if it was anyone's business to see to such things, and if public opinion and politicians and patriots understood what are the things that matter.

The Urgent Need for Suitable Outdoor Bathing Conditions for Women and Girls

If we had, for instance, a Ministry of Health, as we must and will, it would be the business of the Minister and his department to see that suitable conditions were provided whereby girls and women could bathe in, say, the Serpentine, safely and decently and to their great profit—and therefore, of course, to ours. Posterity will marvel that the nation which produced Herbert Spencer, and which, mainly through him, was the pioneer of modern civilisation in the liberation of girlhood from the foolish restrictions of the past, should have contentedly allowed all girls and women to have been excluded from the Serpentine during such a summer as the last, exactly half a century after Spencer's great little book was published.

The best bathing of all—not, of course, for all, but for most—is sea bathing. This being the experience everywhere, and its saltness being the most notable characteristic of sea water, after its wetness; we may abstract the salt, if we will, and add it to our baths. The results are not the same. It is not here said that the salt is not worth adding. Perhaps it is, but the difference it makes to an ordinary bath cannot be great, though sometimes rheumatic troubles appear to yield to the use of hot salt water with massage. Even so, it is doubtful whether the omission of the salt would have made much difference. Those who like to add sea salt to their baths are not here advised to discontinue it. They may be right—right in general, or right for them. But anyone who supposes that it is the saltness of the sea that matters in sea bathing supposes nonsense.

When Sea Bathing is Likely to Prove Injurious to the Bather

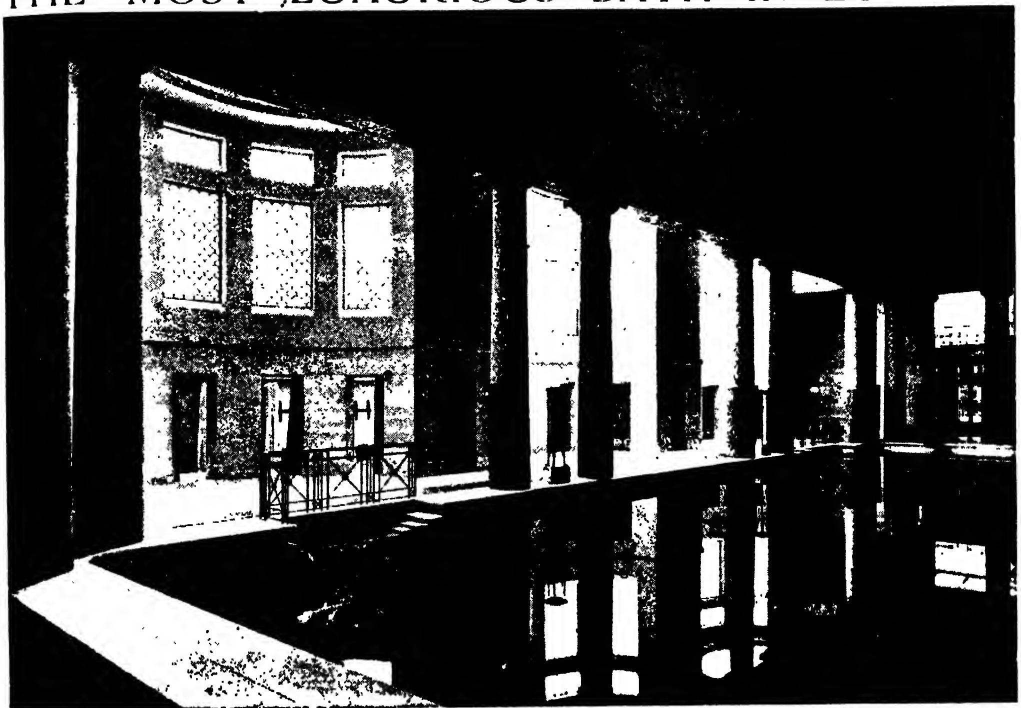
Let us remember that none of these salts enter our bodies through the skin—not to the extent of a single molecule. They may enter by the mouth, but this method of administration is not favoured by the experienced, even though the internal value of salt water may be very great. The total action of the salt is therefore upon the skin, not through it; and, as our skins tell us, that action must be small, for we notice little or nothing. If the salt were allowed to remain, as by putting our clothes on while we were wet, there might be more results, perhaps; but we do not need to look far to realise that it is the total effect of the bathing that really matters.

The proof of this is furnished at once by the tired, unwilling, frightened, or even unaccustomed solitary bather. The sea is as salty as usual, the water may be warm enough and the sun shining. Yet in such cases the bathing may only do harm. The bather who knows no such thing as indigestion, may find himself promptly rejecting his next meal, simply because he has shocked his nerves into erratic action. The frightened child may have night-terrors or, at any rate, nightmares. The young girl may have important bodily functions interfered with, or arrested. Such and many other consequences may follow from sea bathing that is ideal in every respect but one, which is that the mental factor of success is lacking.

The Unique Combination of Factors which the Virtue of Sea Bathing

Many people are only slightly sensitive to this factor, and some are exceptionally sensitive, but though we vary, the fact remains that the real virtue of sea bathing at its best, which has restored so many people to life and health and usefulness and beauty, depends upon the extraordinary and indeed unique combination of factors with less than which we should never be satisfied, for ourselves or for those whom we love. It is against the forgetfulness of this

THE MOST LUXURIOUS BATH IN LONDON



Within the last few years considerable attention has been paid to the provision of suitable swimming-baths in this country, and these photographs show the newest and most luxurious baths in London.

From photographs taken at the Royal Automobile Club, Pall Mall, by Messrs. Bedford, Lemere & Co.

truth that we protest when we criticise the employment of sea salt in the bath water as a substitute for the light and air and sand and swimming and waves and company and sense of strange return to something natural but unknown and unaccustomed, and joy in skill and courage, which belong to bathing in the surf, and to that alone.

The Vital Factor which Must be Present Before We Bathe in the Sea

Man is not a body, nor is he a mind. He is both. They move together, act and react on one another. Water, labelled morphia, injected under the skin, will often relieve severe pain and produce sleep. Salt in one's bath, if one believes in it, may be precious, for memory's sake and for its influence on mental expectation. With a creature so complex as ourselves, and compounded of such utter opposites as body and mind, all things, or nearly all things, are possible. But what is not possible is to understand the influence of anything upon such a creature unless both mind and body be taken into consideration. That is the error of those who impose such things as sea bathing upon themselves or others, and especially the young, without seeing to it not only that the sun is bright as the child goes in, but that the child's eyes are bright as well. It is cruel to a child or a convalescent to prescribe treatment of such a kind, when the vital ingredient, which is called happiness, and is not stocked at ordinary pharmacies, has been left out; and not only may serious injury be done at the time, but a permanent distaste may be given for what is perhaps the finest and most delightful exercise in the world. It is not funny to be frightened in the water, to swallow salt water, and to feel no bottom under one's feet when one cannot swim, or has only just learnt. To discuss the salt's action on the skin, or the sun's action upon it, and omit such considerations, is to have pierced no further than the skin of this subject.

The Value of the Sun's Rays on the Surface of the Skin and Its Deepest Workings

No doubt the exposure of the skin to the sun's rays must be of importance in such sports as sea bathing, and it may briefly be referred to, though our subject is water, for the two should go together. In recent years sun baths have become fashionable, and there are many places abroad, and even one or two in this country, where arrangements are made for people to expose practically the whole of the skin to the sun's rays, even for hours at a time. There are many factors in this question, and we ar[e] only beginning to learn of them. Th[e] composition of sunlight varies in differen[t] conditions of the air, and its various com[]ponents are markedly different in the[ir] action upon the skin of the body. Whe[n] the breathing of some dogs was carefull[y] observed, it was found that they consume[d] sixteen per cent. less oxygen in a give[n] time when their eyes were bandaged, tha[n] otherwise. We consume less oxygen durin[g] sleep. Neither of these facts is reall[y] conclusive, but they suggest what is ver[y] probable on other grounds—that the actio[n] of light on the body is not only cutaneou[s] (on the skin), but affects its deepest work[]ings. There is, at any rate, no doubt fo[r] us, in relation to sea bathing, that the su[n] is of great value by its exhilarating effec[t] though whether one would not need som[e]thing more subtle even than the chemistr[y] of oxygen to measure this effect, ma[y] well be questioned. Nervous bathers ma[y] dislike a grey sea, and not profit by thei[r] bathe, but if the sun shines, the bathe wi[ll] be enjoyable, and therefore useful.

The Exercise which Brings Brain, Body and Soul into True Relation

The *therefore* does not always follow, bu[t] neither does the contrary follow—that onl[y] what one does not enjoy is useful. Th[e] more enjoyable a bathe is, the better it is and though light has often been called th[e] best tonic, it is dull and impotent compare[d] with happiness, which is the best tonic o[f] all for old or young, well or ill. Th[e] observation of doctors thus is that some[]times their patients do splendidly under [a] course of sun baths, and sometimes the[y] go from bad to worse. The evident con[]clusion is what, indeed, inquiry shows Owing to the other circumstances of th[e] visit, the one set of patients have bee[n] happy, and the others have been unhapp[y]. The wisdom of old has long taught us that [a] merry heart doeth good like a medicine; it i[s] so true, that the medicine alluded to ha[s] yet to be found.

In the judgment of the present write[r] an essential part of real sea bathing, looke[d] at from the point of view of health, lies i[n] the ability to swim. Anyone can learn t[o] swim, and everyone should. It is no[t] difficult; it is enjoyed by everyone who ca[n] do it, and it is the exercise of swimming and the swimmer's encounter with the water that give an essential part of its complet[e] value to sea bathing. The exercise is no[t] all, though it is much. Certainly it is quit[e] as complete, as symmetrical—in breast

"THE SENSE OF SOMETHING NATURAL AND STRANGE" THAT COMES TO US IN THE SEA

The healthful properties of sea-bathing lie not in the saltness of the water, but in the unique combination of light, air, sand, waves, joyous company, the sense of a brave return to something natural but strange, combined with the vital ingredient of happiness. M. H. Caffieri has expressed this admirably in the accompanying picture.

swimming—and as suitable for the structure of the body as any that can be named, even including walking, for which the body was certainly not designed; but similar exercises in other conditions do not have the same result. It is the mental factor of swimming in the surf that counts; the exhilaration and stimulation and sense of fitness and self-confidence that come from our transient mastery over the magnificent and immeasurable forces that surround us.

Of aviation the hygienist must not speak until it has been sufficiently studied from the hygienic point of view, but in any case it cannot have the personal quality of swimming, in which the brain to control and the machine to obey are all one, and sentient everywhere. The reader is therefore earnestly counselled to recognise the value, for self and others, of swimming as part of bathing, and especially of sea bathing. Later, we must consider the laws of health as they are illustrated in exercise in general, but here is a unique exercise which is much more than exercise—*as any exercise worth a straw to the complete man must be*—and which brings the brain, the sentient soul, and the sensitive surface of the body into nearer relation than anything else.

So important is this subject, that it is scarcely worth while, in comparison, to study the effect of baths which contain special kinds of water. That subject may have its place in dealing with certain forms of disease, but the healthy need not deceive themselves. There is a famous Continental spa which has a unique reputation in the treatment of heart disease. The patients are bathed in the water, which is effervescent. The utility of a visit to this spa has been put down to the composition of the water in which the patients bathe, and the salts and other ingredients have been extracted, and one has spent much time in observing their influence upon heart disease when added to the patient's bath in this country. The result was precisely nothing—a very important result to be ascertained. The visit to a spa of one kind or another may do what nothing else could do for the person in question, but the beneficial agent, *par excellence*, cannot be bottled by any chemistry that ever was or will be.

But, indeed, Robert Louis Stevenson has expressed in an admirable passage much of what we have said in these pages. The reader has been patient; here is his reward: "To wash in one of God's rivers in the open air seems to me a sort of cheerful solemnity or semi-pagan act of worship. To dabble among dishes in a bedroom may perhaps make clean the body, but the imagination takes no share in such a cleansing."

CARRYING POWER INTO THE FOREST

The old laborious and slow way of cutting down trees by hand has given place largely to power methods. A steam or a petrol engine is transported into the forest to drive a saw which cuts the tree off close to the ground, and then saws it up into short pieces if desired. This picture shows a petrol driven chain-saw in the act of cutting off a huge trunk.

THE POWER OF MACHINES

The Transference of Labour from Men to Machines—The Iron Man with the Hands of a Thousand Human Men

MACHINES WHICH WORK BY THEMSELVES

THE Epic of the Triumphs of Machinery has yet to be written. Is the subject an ignoble one? To those whose minds have been moulded by the Epics of History, the triumphs of machinery do not, perhaps, appeal. The struggles of kings and dynasties in which the blood of the people has been spilt for naught engage the pens of historians, and form the themes of poets. Little do we know of the mechanical arts by which the world's wealth has been won. Incidentally, we learn how persecution has driven skilled workmen from France and the Netherlands to England, and the Pilgrim Fathers to Massachusetts, but the history of industrial growth remains yet all but unwritten.

A great prose epic of machinery and crafts awaits the pen of a Carlyle or a Ruskin. The triumphs of peaceful industry may yet be invested with a glamour surpassing those of war. Let us think for a moment.

Within a little more than a century an enormous proportion of the world's work has been transferred from the lissom fingers and the energies of the craftsman and the labourer to machines which never tire, machines which never make a mistake, which belittle the attendants, who occupy a very small and mean relation to the quantity of work produced. Many of these giant machines now embody the force of five hundred men, a few represent the strength of eight hundred or a thousand men. Many of the smallest have the energy of from twenty to fifty men.

And this is only one way in which to regard machinery. If regarded from another aspect, that of the quantity of work done, many single machines, often the smallest, will easily do more than a thousand men could do. And, besides, as they never weary, they will run through night and day, and are compelled to do so in times of stress of business from Monday morning to Saturday night without a stop, except for a few moments to remove finished work and replace material, or sharpen tools. The attendants on such machines are little more than automatons.

All the machinery in the world and all the tools are constructed of metal, mostly of great hardness. Nearly all this metal, after having been prepared roughly to shape by melting and pouring into moulds, or by hammering and forging while white-hot, has to be cut and shaped carefully in machines to its final and proper form, ready to fit into place.

If we go into the hives of industry, where engineers and metal-workers construct the myriad forms in which machinery is built, and the equally numerous forms in which materials are worked into commercial products, the workers are belittled by the overwhelming dominant machines. The infinitely great and the infinitely little in the teeming universe of living things appeal powerfully to the imagination. The ideas which are suggested by mass and power in contrast with the minute also crowd through one's mind in a big machine-shop. Some machines are so light that a child might lift them, others weigh a hundred tons and more. These big machines take shavings off the thick armour-plates of Dreadnoughts, or they bore the casings of the huge turbines which drive the battleships, or they turn the revolving parts of turbines and big machinery, shafts, and wheels.

All these are cut slowly but accurately by these Titanic machines. The big guns for the warships are made also entirely with the help of machinery. And then, if one wanders into another part of the same

WHERE THE MACHINE REIGNS SUPREME

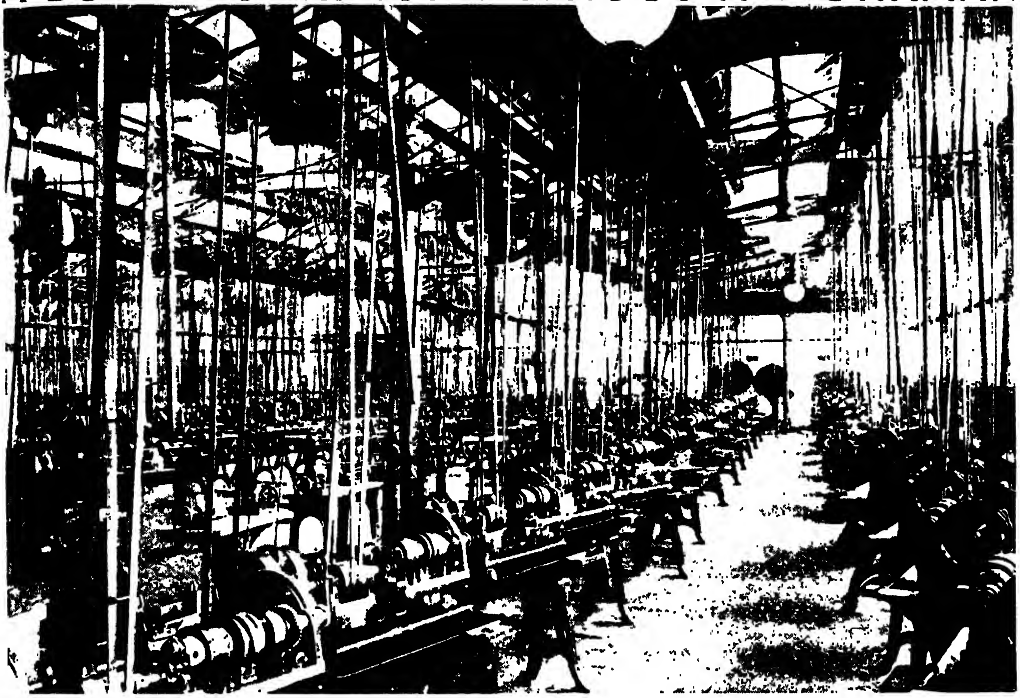
A VISTA OF AUTOMATIC SCREW-MAKING MACHINES

This picture represents the highest development of machines for metal cutting. All the machines in this shop work day after day, week after week, year after year, without human intervention, beyond that of feeding them with rod from which the screws are cut, supplying oil at intervals, and occasionally sharpening the tools.

A WILDERNESS OF IRON AND STEEL INSTINCT WITH LIFE

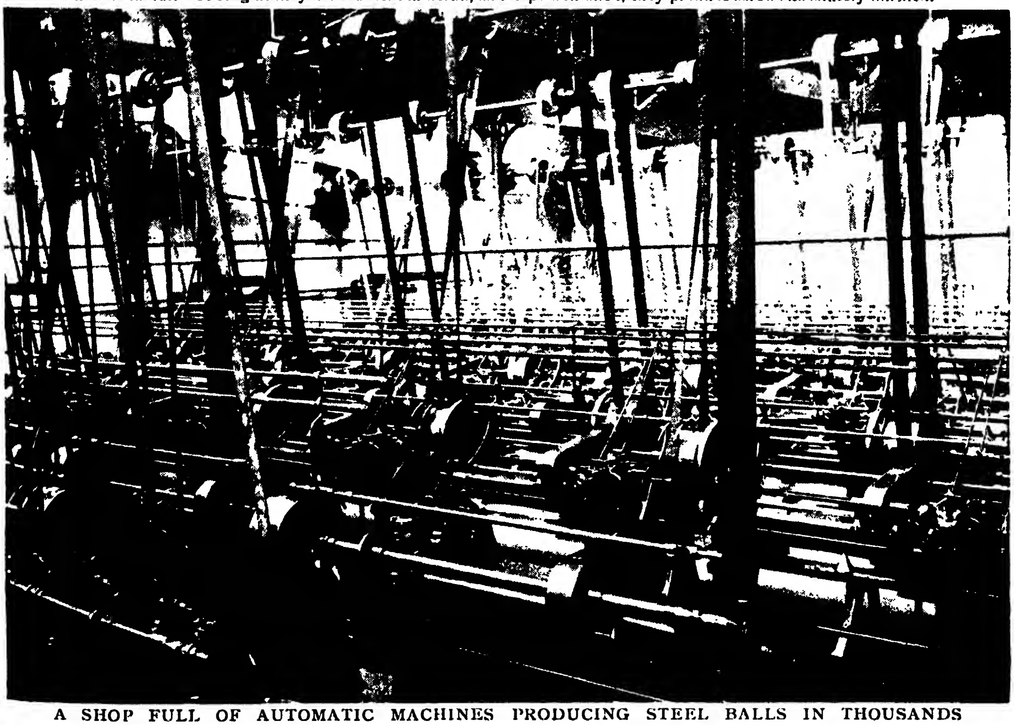
Here we have a typical glimpse of what a large machine-shop is like. Note the huge machines ranged down the sides, and the powerful head travelling cranes which are necessary to pick up and transport the massive castings and forgings which have to be "tooled," some of them weighing forty, fifty, and sixty tons.

A BUSY WORKSHOP WITHOUT A WORKMAN



THE MECHANICAL WORKMAN—THE ULTIMATE RESULT OF AUTOMATIC MACHINERY

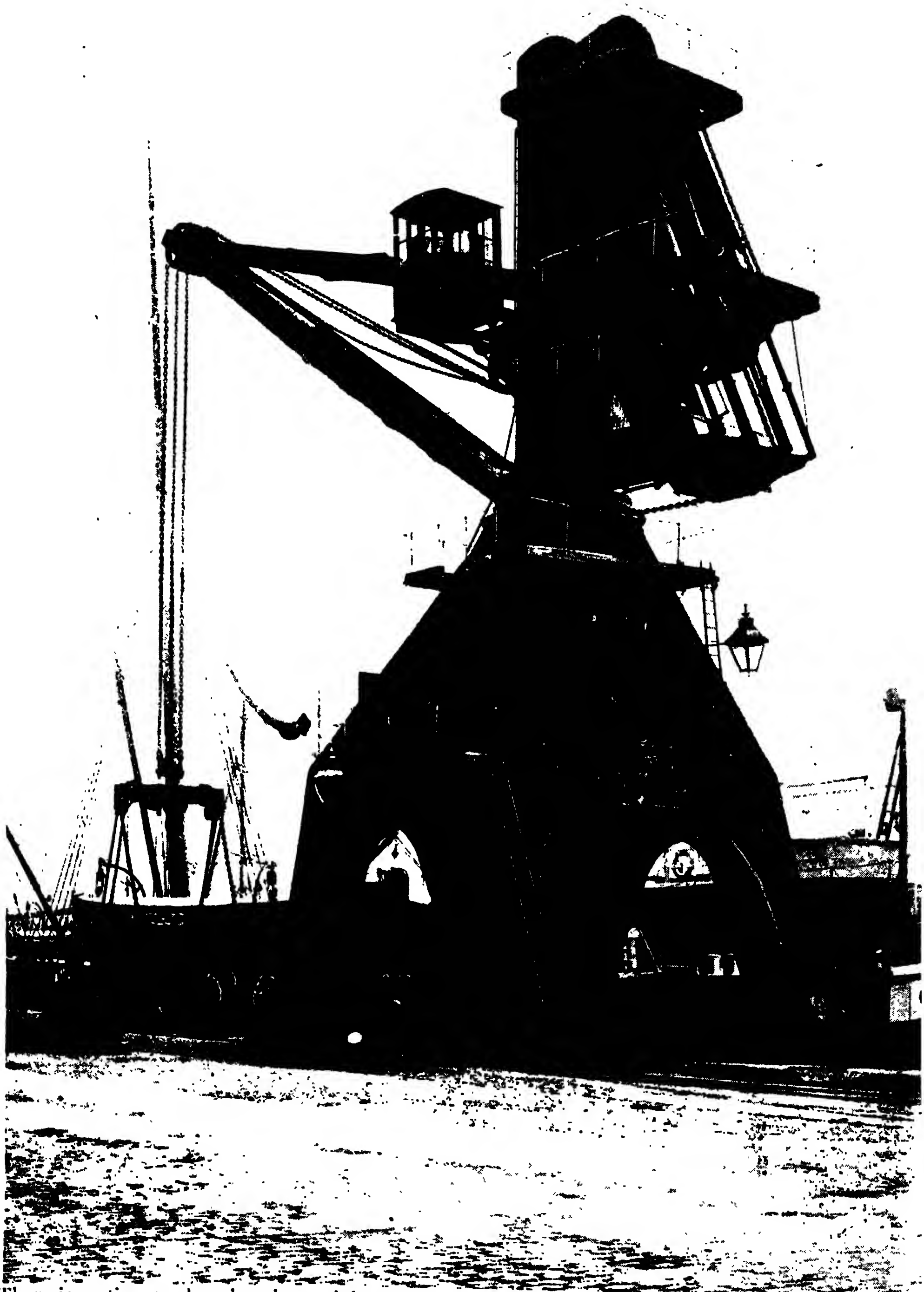
A busy workshop with not a single workman is the ultimate achievement of this Age of Machines. In this photograph we see a workshop full of screw-making machines that do their daily tasks entirely by the mechanism embodied in them, without being touched by human hands. So long as they are fed with material, and kept well oiled, they produce screws absolutely finished.



A SHOP FULL OF AUTOMATIC MACHINES PRODUCING STEEL BALLS IN THOUSANDS

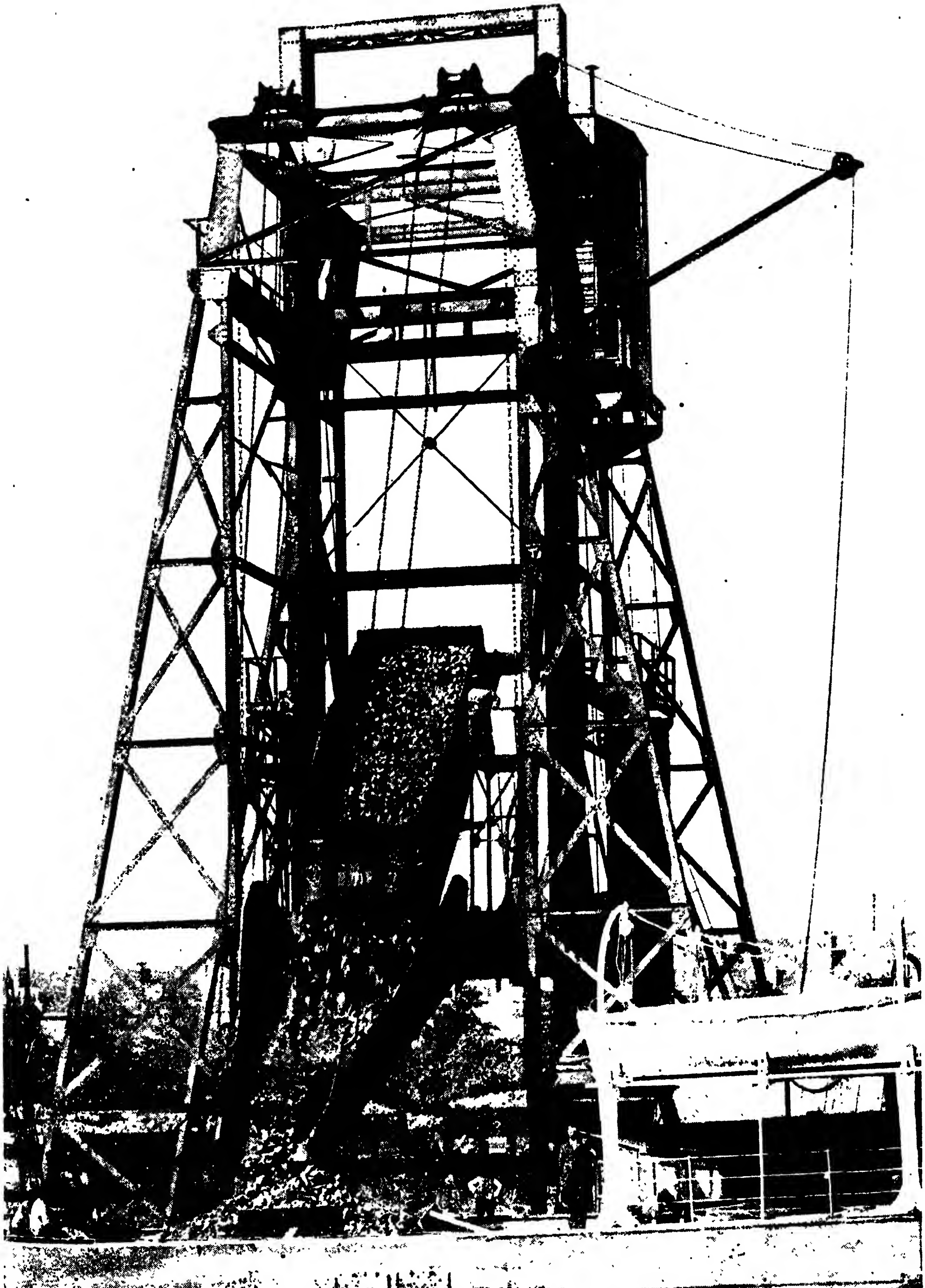
The enormous extent to which ball-bearings are now used in all classes of machinery has created a great new industry, and millions of balls are made each week in the factories of the world. This picture shows a shop in which the balls are turned by automatic machines.

20 TONS OF COAL SWING OVER A SHI[P]



There is no time to shovel coal out of the trucks when coaling a big ship with thousands of tons. S[o] the truck is lifted bodily from the quay, with its twenty tons of coal, swung round by a huge hydrauli[c] crane, and tipped up so that the load shoots down into the hold. Then the empty truck is swun[g] round again on to the quay, and another one picked up.

LOADING A THOUSAND TONS IN AN HOUR



This picture shows a great coal "tip" which raises a railway waggon-load of coal, tilting it up and opening one end, so that the coal slides down a chute reaching out over the ship, and drops into the hold. More than one thousand tons can be loaded in an hour in this way, and this saving of time is of great value to the shipowner. Hydraulic power operates the tip.

establishment, the little machines stand marshalled in rows, cutting all conceivable shapes, round and flat; making screws, gears, and the innumerable requirements of the engineer. Hundreds, often thousands, of these machines occupy the areas on floors and in galleries in a single big establishment. Many seem as though instinct with life, since they require no attendance when in operation. Many others require a small share of notice and watchfulness.

Many Machines that are Only Quite Simple Tools Worked Without Immediate Human Control

But always without exception the machine is more than the man behind it; its movements alone cut and shape the forms of metal entrusted to its charge, and the men are attendants—hands, operators, chargemen, machine-minders only, whose duty lies in feeding the imperious demands of the inanimate but powerful and accurate machines which they have to supply with materials.

It was not always so. Nearly all these marvellous machines have been developed through the nineteenth century. Only a few crude machines existed before those great pioneers of metal-cutting, like Henry Maudslay, Sir Joseph Whitworth, and their compeers, very giants among mechanicians, showed their successors the way to design and to build machines to cut metals. We have often seen a carpenter cut wood with a chisel, a saw, or a plane, or an engineer cut metal with a chisel or a file, or make holes with a drill. The main idea of the machine-tools which fill the workshops is nothing more than that of taking a chisel, or a saw, or a drill from the control of the hand, and placing it under the coercion of a rigidly constrained mechanical movement.

It is curious to recall how some of the early machine-tools had the name "Iron Man" applied to them. The beginnings of this idea go far back into prehistoric ages, when neolithic man attached a celt to a handle, or a drill to a fiddle-bow.

The Tool that is Small and Simple, but Must Have a Strong Machine to Drive It

Yet it is only about a hundred and fifty years since the tools used in the turning-lathe were first taken from the workman's puny hands, and fastened on a mechanical carriage, which resulted in the "slide-rest," a fitting which is present in some form or other in nearly all machine-tools. This epoch-making invention began to revolutionise the methods of cutting metal. It gave a means of controlling the tool, and of enabling it to far excel any workman in power and in accuracy of cutting.

It is remarkable, in the vast arrays of machines which are at work in the machine-shops, how utterly insignificant a thing the actual element—the cutting tool—appears. It is generally a small bar of steel, which a child could pick up with one hand, yet the whole structure of the huge machine has been designed and built with the object of enabling this little cutter to do its duty upon the surfaces of the iron and steel castings and forgings entrusted to it. And the movements of the machine are often of an extremely complex character, involving a cost of hundreds or thousands of pounds to construct it.

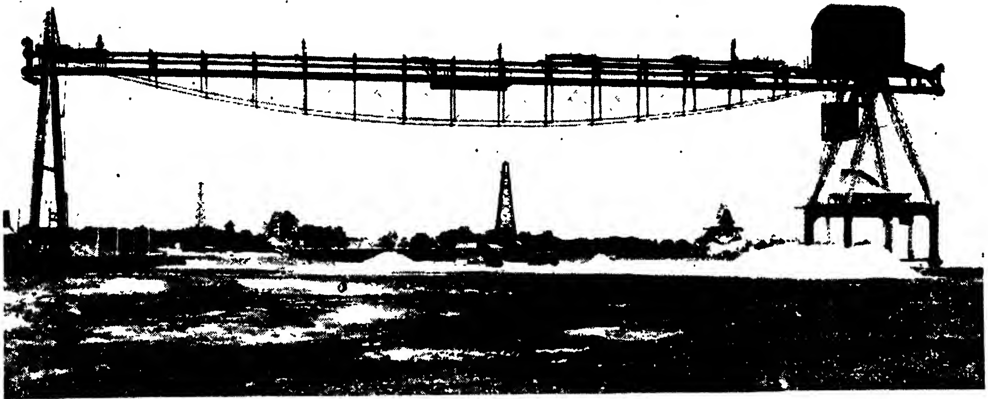
Why not, then, make the tool much bigger, so as to cut the whole width or length of a surface at a stroke, instead of slowly nibbling at it with a narrow point of a tool? The reason lies in the great difference between cutting iron or steel, and soft materials like wood. Everyone knows how easily a chisel or a knife will cut wood. Yet if we try the same tool on iron it will do no more than inflict a scratch, and damage itself in doing that. By lessening the keenness of its edge very much, and putting it in a machine, it becomes capable of taking shavings from iron, but at a much slower, a painfully slower, rate than wood can be shaved off.

Many Tools Combined in One Huge Machine of Enormous Strength

And so the wider we make its edge and the more we try to cut, at once the greater is the resistance, until at a certain stage it is quite impossible to force the tool to its work without breaking it, and damaging the piece of work, and the machine into the bargain.

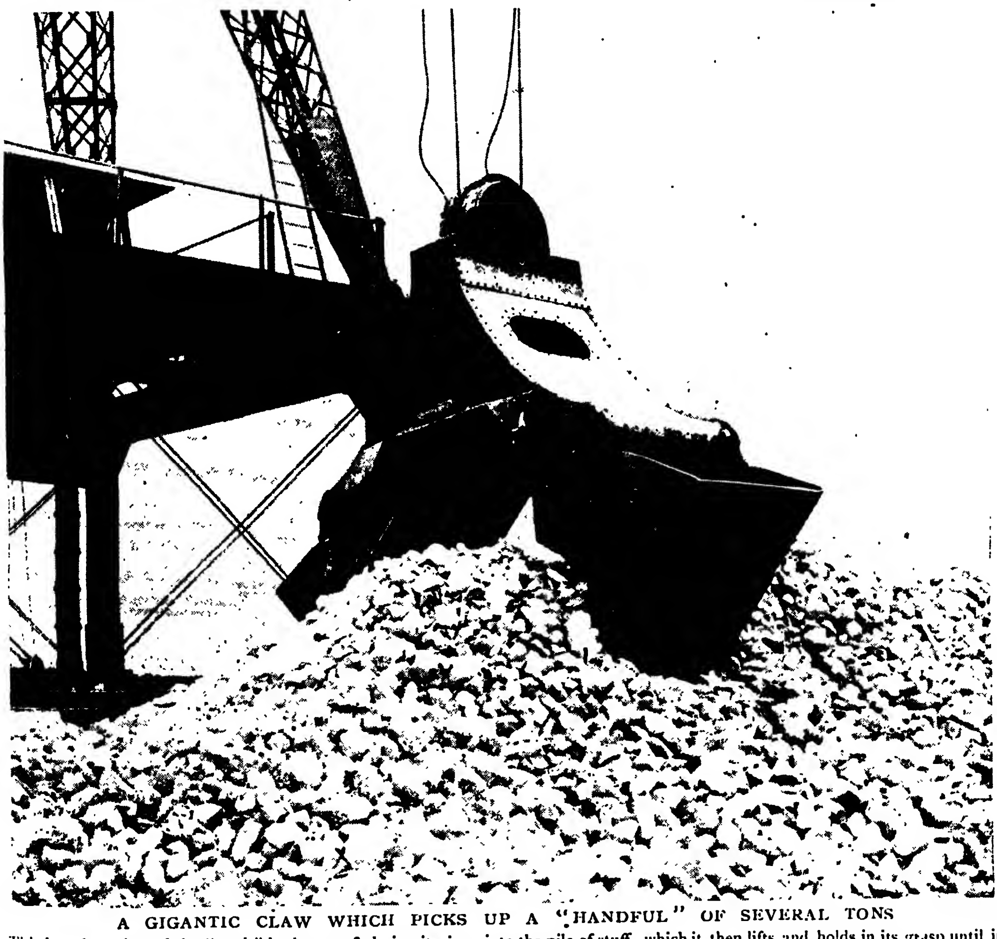
This is why such an insignificant-looking tool does the work of cutting over a large surface, or turning a shaft or gun, or boring a cylinder. Though the actual tool is always small by comparison with the machine, there is a way of increasing the output of machines by multiplying the number of tools held in one machine. Some kinds of turning-lathes have four, eight, or more tools cutting simultaneously at different parts of the piece of work being machined. And the tools have not always a single cutting portion on them; there is very much machining done with rotating tools, called milling cutters, which are like very wide saws, and have a number of teeth, which each take a little shaving off the metal as the cutter revolves, like a paddle-wheel churning into water. In drilling holes, an immense amount of time is saved by increasing the number of drills.

SAVING THE LABOUR OF HUNDREDS OF MEN



A GIANT TRAMWAY CRANE WHICH DOES THE WORK OF HUNDREDS OF MEN

This photograph shows a large "tramway' or travelling crane which works the "grab" seen in the lower picture. The grab can be hoisted and moved to and fro or sideways with great rapidity, to convey and drop the stuff picked up from the ground.



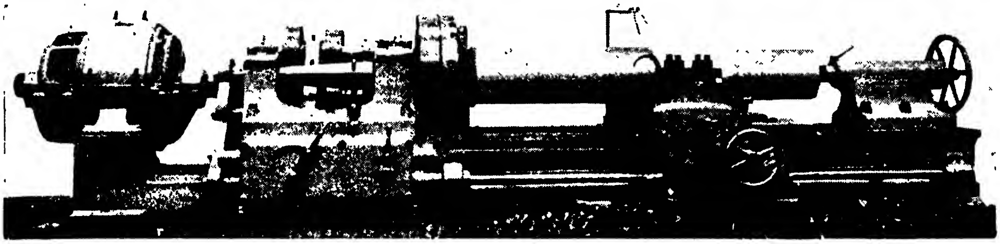
A GIGANTIC CLAW WHICH PICKS UP A "HANDFUL" OF SEVERAL TONS

This is a close view of the "grab" in the act of closing its jaws into the pile of stuff, which it then lifts and holds in its grasp until it has to be released again, at any position to which the crane has transported it. The only man-power required is that on the crane, for working various operating handles.

SHAPING ENGINES FOR WIND AND WAVE

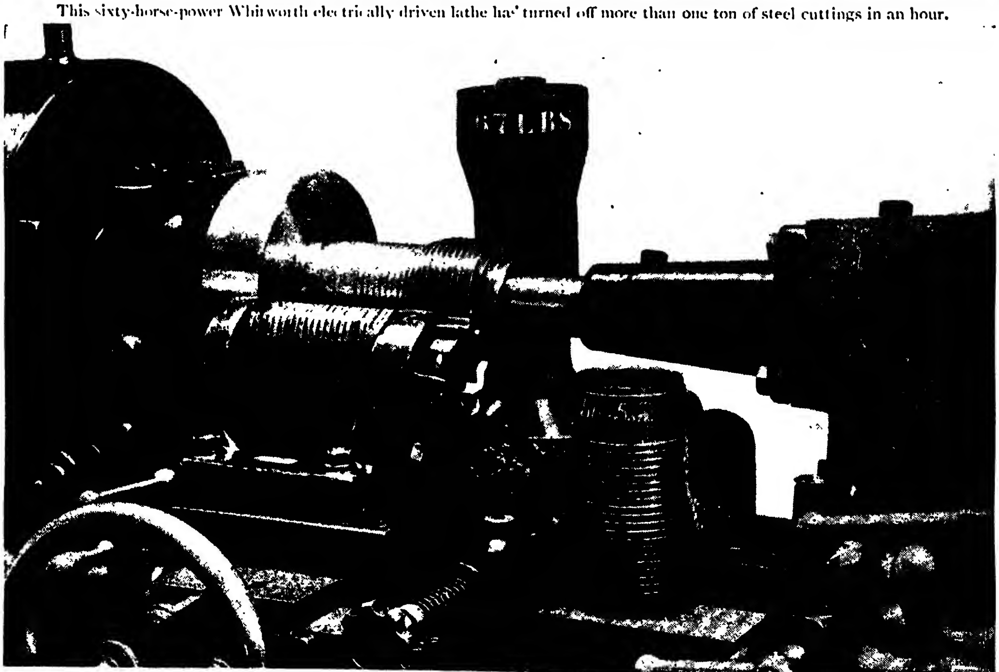
A MACHINE THAT NEEDS THE POWER OF SIXTY HORSES TO DRIVE IT

The crankshafts and other forgings required for marine engines are so massive and difficult to turn that lathes of the kind seen in this picture have become necessary. There are no belts to drive it, but the sixty-horse-power motor seen at the top left-hand corner turns the gears and drives the shaft. The little ten-horse-power motor below it is for moving the "tool carriages" about quickly.



A LATHE THAT SHAVES OFF A TON OF STEEL CUTTINGS PER HOUR

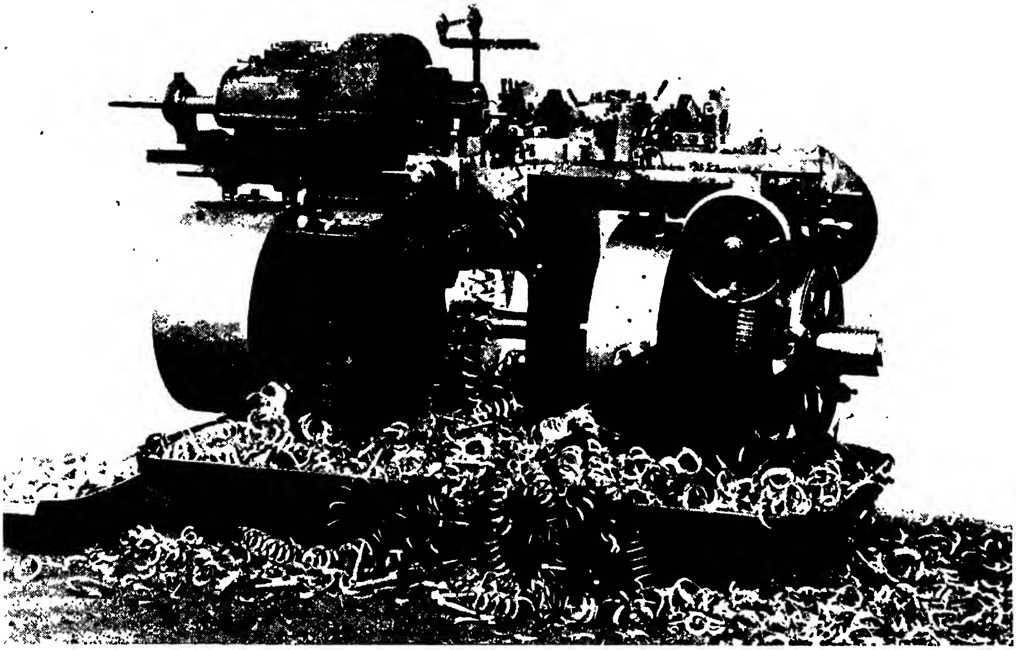
This sixty-horse-power Whitworth electrically driven lathe has turned off more than one ton of steel cuttings in an hour.



HOW THE GNOME AEROPLANE CYLINDERS ARE MADE FROM SOLID STEEL

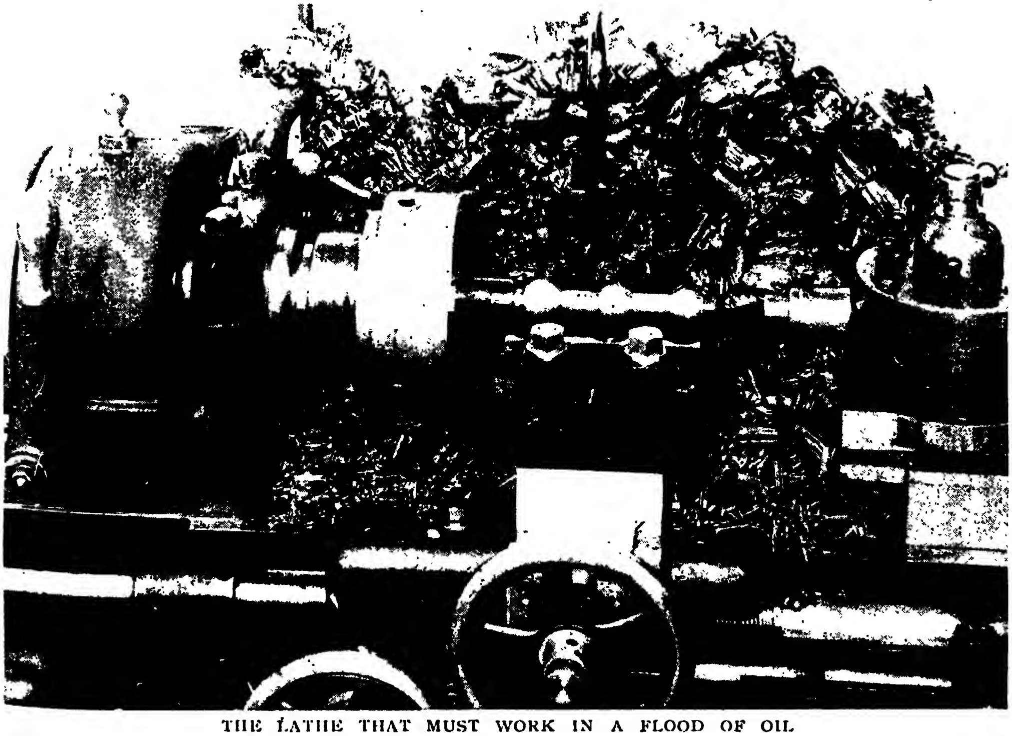
Motor cylinders are usually cast to shape, and bored out afterwards. The makers of the famous "Gnome" aeroplane engines take a solid steel forging, which is known to be homogeneous throughout, and bore and turn the ribbed cylinder out of this, the finished shell being very thin, yet immensely strong. This picture shows the simultaneous boring and turning on a "Herbert" lathe.

THE MACHINE THAT WORKS BY ITSELF



AN AUTOMATIC TURNING LATHE THAT WORKS BY ITSELF, MAKING STEEL BOLTS FROM A LONG BAR

This is the most wonderful machine in an engineer's workshop. Fed with a piece of steel bar, it is able to make screws, bolts, and many other kinds of things which are cut to shape by a number of tools that come up, do their share of the work, and retire again to let others act, all with the utmost precision, and without human intervention. Note the strong steel shavings, thicker than shavings of wood.



THE LATHE THAT MUST WORK IN A FLOOD OF OIL

This picture gives a good idea of the way in which shavings are cut from a hard steel bar. The tool forms the three globular shapes and the straight parts between them all in one movement, and the chips curl off in such profusion that they would soon bury the lathe if they were not removed at frequent intervals. Oil is pumped on to the tool and the bar, flooding them all over to keep them cool.

as many as thirty or forty drills descending simultaneously and boring their way into the metal in the same period of time that one drill would do one hole. Many machines will drill holes at both ends of a long cylinder or pipe simultaneously.

All this cutting demands a large amount of power to hold the tools to the work and to force them along, or to force the work along, as the case may be, otherwise the machine would stop for sheer want of driving force, or something would break.

Steel that Will Cut when It is Red-Hot, and Run for Hours Without Sharpening

The power behind some machines is enormous, considering it from the point of view of a person unfamiliar with the difficulty of cutting metal. The big lathes require as much as from sixty to a hundred horse-power to cut the chips off, and this continuously all day while the lathe is turning. The terrific pressure produced in the operation of turning may be imagined from the fact that for every square inch of steel removed by the tool there is a pressure of a hundred tons on the tool, trying to push it away. It is no wonder, therefore, that the heat generated in cutting often makes the end of the tool acquire a red-hot temperature, and the shavings cannot be touched as they curl off with a crackling sound, to the accompaniment of smoke.

Many tons of steel are thus removed on some lathes in the course of a working day, and they keep a labourer pretty busy in taking them from the floor and carrying them out of the way. A new kind of steel for the cutting tools, only introduced during the last decade, has further immensely increased the output of machines, because it will cut very much faster than the old kind of steel previously used—three or four times as fast—and it does not become dulled nearly so quickly, so as to require re-sharpening.

The Wonderful Adaptability that Comes from Standardising Parts of Every Mechanism

A tool does not necessarily bear the slightest resemblance to the form of the work which it cuts into shape. It may be only a straight piece of bar with the end ground into a curved or a straight shape, and the rest is done by the controlling influence of the machine, which moves and adjusts the various parts in such a manner that the desired outline is given to the metal. On the other hand, there may be some recognisable feature about the tools, which gives a clue to their purpose: and when one operation has to be repeated day after day on hundreds or thousands of pieces identical in shape, the tool may "fit" the work very closely, simply because it pays to make it specially for that one purpose.

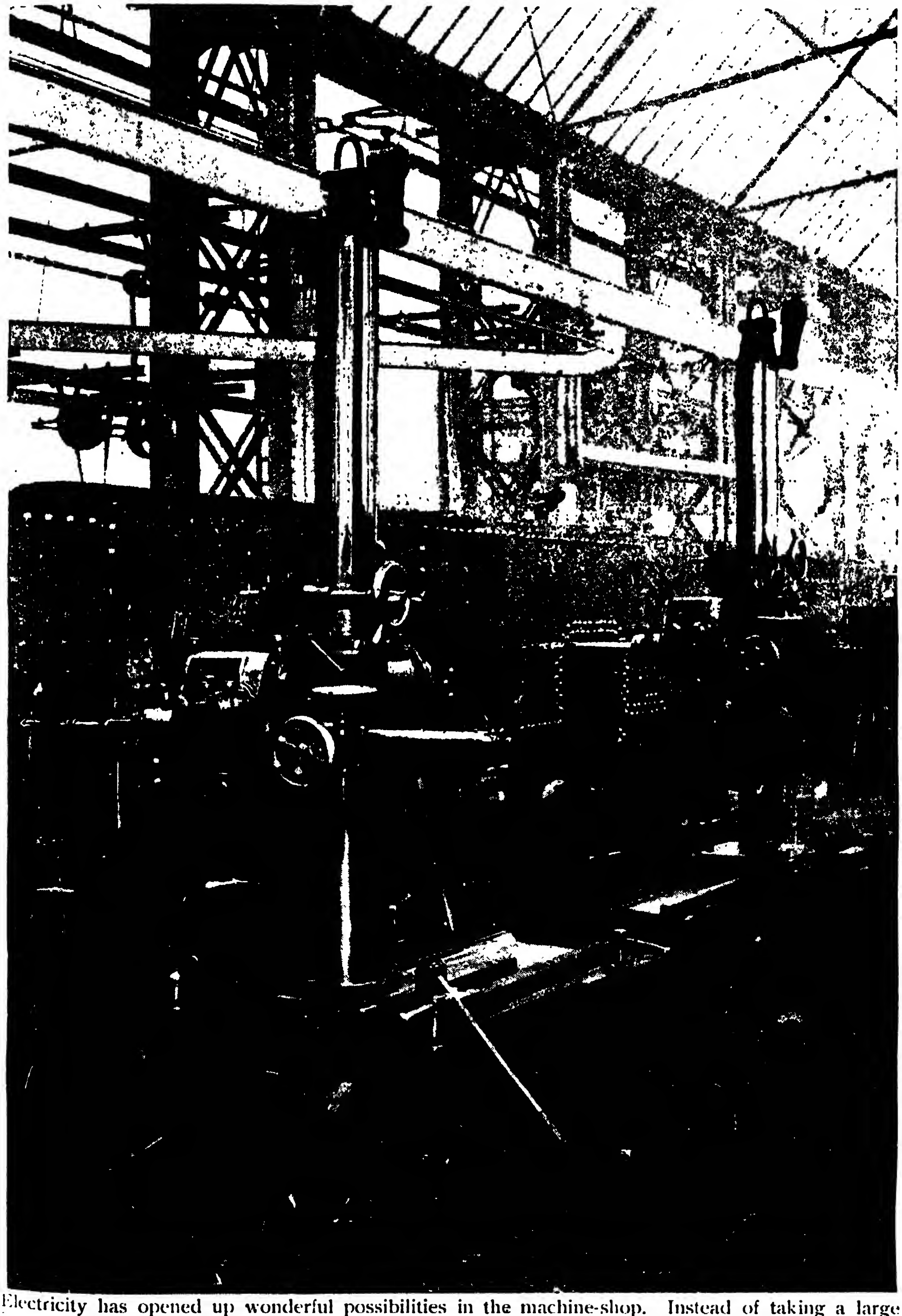
So wonderfully is the science of cutting metals carried out in workshops that produce hundreds of similar mechanisms, as sewing-machines, typewriters, cash-registers, or guns, and so accurately do the machine-tools operate, that it is possible to take any part from a heap and fit it to its place in the mechanism without filing, or dealing with it by hand in any way. Inspect the parts of a motor vehicle, an engine of any kind on land or at sea, a crane, a watch, a clock; examine the spindles, the gears, the screws, the valves, the joints, and the rest, and try to conceive by what means all these parts were so beautifully fashioned. Go a stage further, and remember that when you see one complete piece of mechanism there are thousands more exactly like it, and that, from any single one in all those thousands, any individual piece can be taken and fitted into any one of any of the other similar mechanisms without adjustment or worry. All this is accomplished by the triumphant machines which perform their tireless tasks, and produce such beautiful results without any meddlesome correction on the part of their attendants.

The Marvellous Accuracy which Science in Its Minuteness Describes as an Inaccuracy

This means that each piece must be of a certain definite size, no larger and no smaller. But as it is impossible for anyone in the world to produce *perfectly* accurate things, engineers must perforce be content with what they call a "limit" size; that is, a shaft or screw or a hole will be within certain sizes, neither larger nor smaller, though a slight inaccuracy may nevertheless be present. But the wonderful part is that this which we call an "inaccuracy" is only measurable in thousandths of an inch. Tissue-paper is about one thousandth of an inch thick, yet this is coarse by comparison with the limits of size which metal parts can be and are cut to. A two-thousandth or a five-thousandth part of an inch is commonly worked to.

A remarkable thing is that these extremely fine limits are regularly obtained, notwithstanding that the tools are wearing away, and that there is elasticity in the machines themselves which is likely to interfere with their accurate working. The finest limits possible are not obtained

POWER THAT IS MOVED FROM PLACE TO PLACE



Electricity has opened up wonderful possibilities in the machine-shop. Instead of taking a large framework to a big drilling-machine to drill the holes, small portable machines are brought to the framing, and moved about into any desired positions, scores of holes being drilled in a short time.

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by the regular cutting tools of steel, but by the revolving grinding-wheels of emery, corundum, and carborundum. This again is a very odd fact, because these wheels wear much more rapidly than the steel tools. And yet it is only by using these that the very finest results possible can be obtained. It is possible to grind to one fifty-thousandth part of an inch.

The Hardness that Cannot be Cut, but has to Succumb to Grinding at Last

Such remarkably fine work as this may be better understood if we mention that a plug and a ring ground so finely to fit each other will, if the plug is inserted in the ring, stick fast unless they are kept in movement, simply by the molecular attraction of the metals. The temperature of the human hand will also make such a fit easy or tight.

As the wheels wear, a compensating arrangement has to be used to make up for that. There is one very ingenious machine which will grind piece after piece to very accurate sizes, allowing for the wear of the wheel, and stopping the grinding at a certain point when the work is finished to size, this being accomplished by a clever electric contact device.

Another thing in favour of grinding is that the hardest materials which cannot be cut with steel tools can be ground with ease. Nothing is too hard to be ground. This explains why we so often see the term "hardened and ground" in relation to some of the parts of a motor-car; the steel is hardened to enable it to resist wear, and it is ground because that is the only way in which it can be finished properly.

How Machines can be Set to Work by Themselves and Know when to Stop

The most remarkable aspects of the machine-tools, as viewed by the stranger unfamiliar with the sight, is the self-acting, or automatic, character of their movements. By these in some cases the tool is moved to a certain predetermined distance, and then runs back quickly to its starting-place without the intervention of the man who stands by. Often these reciprocating movements are performed by a table on which the piece of work is fastened. Or, again, the tool cuts deeper and deeper at each successive reversal, and when the correct depth is reached it will not work any longer, but ceases its movements.

Or if a gear is having its teeth shaped, the spaces between the cogs or teeth are all made exactly alike, being divided round by the machine itself as the gear rotates in the brief intervals of cutting. Or if a drill is making a hole, the machine sends the drill forward by a precise and measured amount at each turn, and we see it steadily descending, often at a rate of an inch in a few seconds. When these movements are once adjusted or "set," they go on operating without intervention.

So completely automatic are some machines that the attendant may leave them for a long while, and he is thus able to look after a whole row, conscious that, excepting by accident, nothing can go wrong, and that the machines will of themselves stop should they have used up all the material he has supplied in the form of bars of iron, or steel, or brass, or other shapes of metal. The ringing of a bell frequently gives warning of the machine having used up its "food."

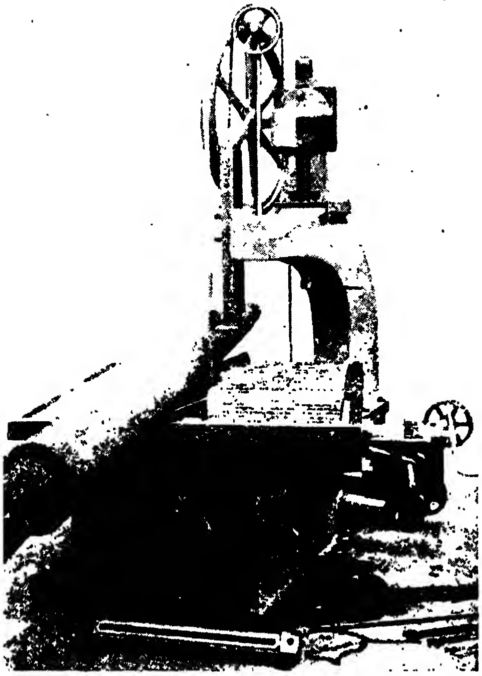
The most wonderful and complete examples of automatic working, which never fail to interest visitors, are the automatic lathes or screw-making machines, which make screws and parts from lengths of plain bar.

Machines that Juggle with Twenty Different Kinds of Tools as They Need Them

Here the tool question assumes a very interesting phase; the tools are multiplied in number, but each one is of a different kind, and they are set around the edges of a rotating holder, called a "turret," which automatically brings the required one round in turn, causes it to cut the work in a certain fashion, and then makes it retreat, and swings round another tool. As many as eighteen or twenty distinct kinds of tools can be thus manipulated, and the only reason for stopping the machine is the need of sharpening when the tool edges become dull. So long as the machine is supplied with one length of bar after another it will continue to produce the screws or other parts. By an ingenious application of fingers and chutes it is now easy to feed these machines with small separate parts which have been cast or forged nearly to shape, and are thus fed, gripped, cut to shape, and again released to make room for the next piece.

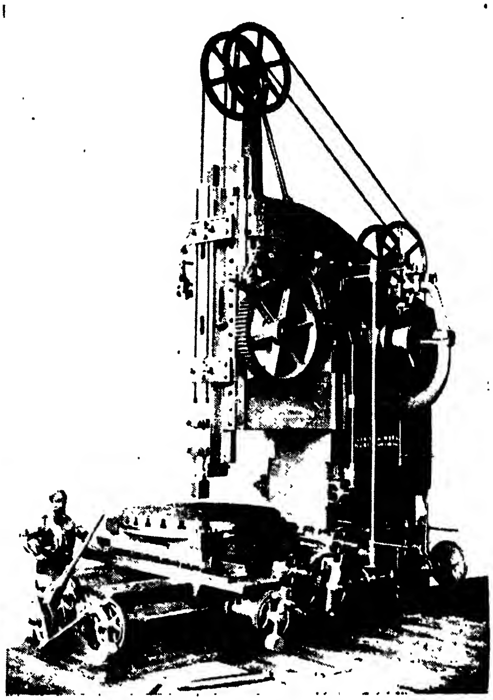
There are many other interesting provisions incorporated in the machines. Some of them are classed as "fool-proof" devices, and, as their name implies, they prevent stupid blunders by careless or absent-minded attendants. The various handles and levers by which the machine is started and stopped, and the movements adjusted and varied in speed, are often interlocked, so that the operator cannot throw in conflicting mechanisms and produce grave injury to a valuable machine.

SAWS & RIBBONS THAT CUT THROUGH STEEL



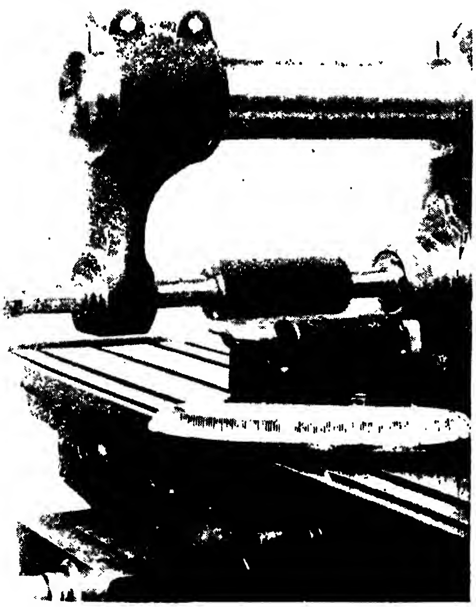
STEEL RIBBON THAT CUTS FORGED SHAFTS

his picture shows a "band-sawing" machine, in which a thin ...less ribbon of steel, with teeth upon its edge, cuts through a steel shaft pushed against it.



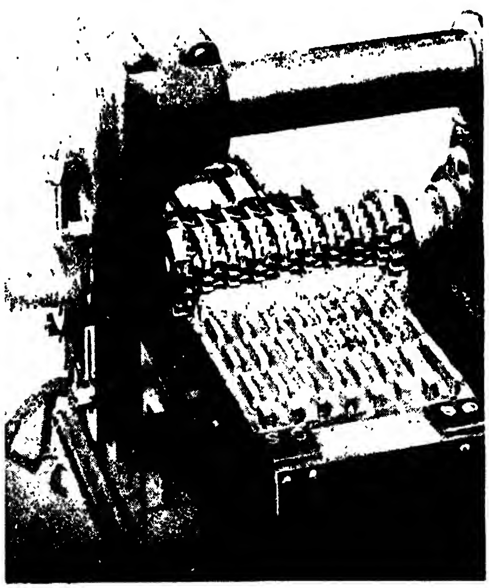
A MACHINE OF GREAT PRECISION

This picture shows a giant "slotting" machine, which has a ram moving the cutting tool up and down, to slice thick shavings off massive iron or steel pieces.



WONDERFUL EXAMPLE OF FINE SAWING

...e we see a marvellous instance of multiple "milling" or saw- ... one hundred and twenty slits being cut in this gas-fire burner at one pass by the revolving saws strung on the spindle.



EIGHTEEN REVOLVING CUTTERS AT WORK

The time of cutting this railway signal interlocking-plate to shape is reduced enormously by making eighteen toothed cutters work on it simultaneously.

So many machines are now compulsorily guarded in parts which contain revolving gears and wheels that the attendant cannot see the internals of the machine; all that he is aware of is the handles outside, and these are numbered, so that by referring to a chart he can see which ones to move in a certain position to get certain results. A boy even may therefore operate a highly complicated machine, of the construction of which he has but the vaguest conception.

The Unwearied Machine that Never Changes Its Endlessly Repeated Work

In machines which cost hundreds or thousands of pounds it is necessary to take precautions against accidents, which perhaps involve a heavy repair bill, and many interesting provisions are made to allow for overstrain through putting too much work on the machine. As the strength of a chain is in its weakest link, so the strength of machines may be governed by an element so proportioned that it will break or shear off if the safe limit of force is exceeded. When this happens, a pin or bar snaps in the driving mechanism, and acts like a safety-valve in preventing further over-working. But for this, shafts would become twisted, gears would have their teeth ripped out, parts of the framing would be cracked, and human life would be endangered.

Injury to workmen is prevented not only by guarding the flying wheels and shafts, but also in more complicated ways. Sometimes a stamping or punching machine is so constructed that it cannot be started unless the attendant places both his hands on levers. He has then no more hands left to get in the way of the descending punch, to be mangled. Or a hinged lever may be arranged so that it sweeps across the space beneath the descending tool, and compels the removal of the worker's hand just in time.

The Long Rows of Machines that Make the Same Things Year after Year

A great difference which is found between the old workshops and the newer ones is in the kind of machines used. In the old shops the machines were and are still of ordinary kinds, on which a whole range of miscellaneous operations can be done. But in the new shops, which make very special products, as engines, motors, and all the wide range of special mechanisms which man finds necessary to-day, the machines differ considerably. There are hundreds of what are called "special" machines, which do nothing but one kind of machining day after day, week after week, year after year, on articles often never varying even in size. There is so much of the same kind of cutting or grinding that it pays a firm to have a special machine for doing that little bit of an operation; in fact, they would lose largely if they did not use such a machine, and the product would be unsatisfactory. Some machines make one kind of gear all the time, another cuts off bars of steel in readiness for other machines, others never do anything but turn railway axles, others nothing but railway wheels or tyres. And not one machine only but long rows of them, are seen in the great railway works, doing the same thing to-day that they have been doing for twenty years past.

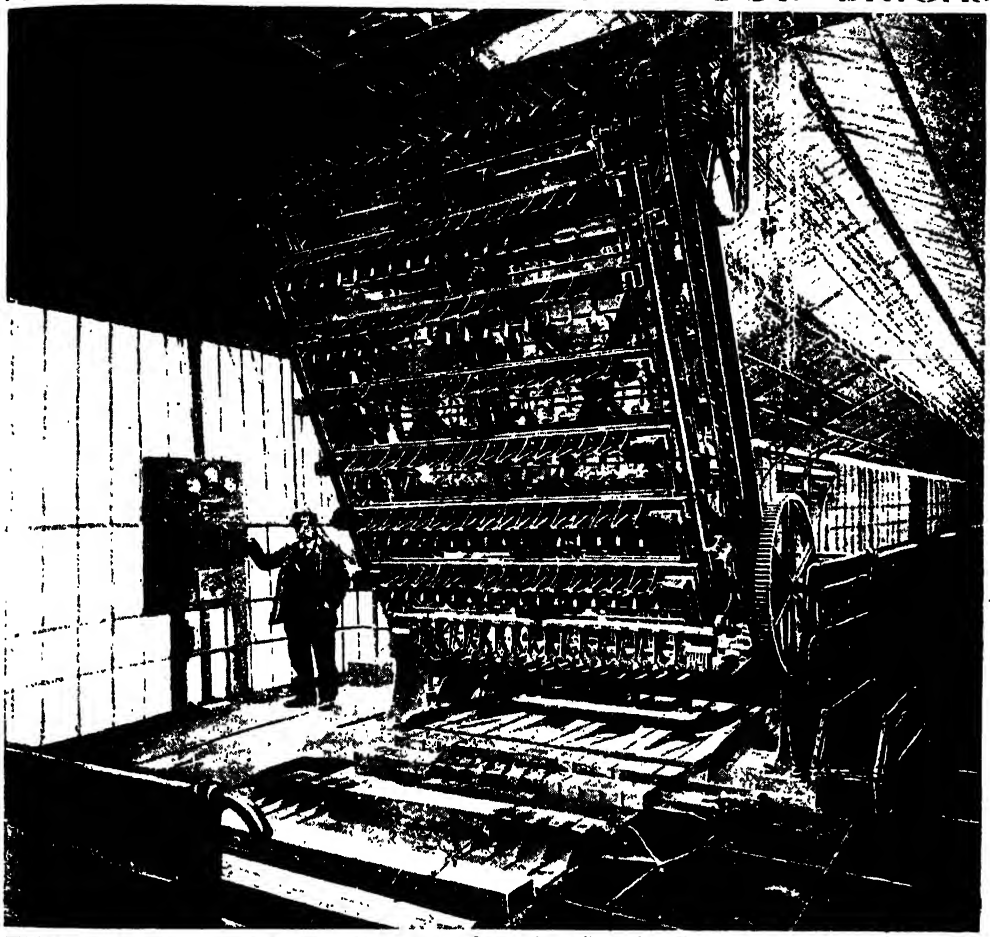
In the automobile industry this specialisation is very marked indeed, and there are special machines for such an apparently trivial function as cutting oil grooves, others for rounding the teeth of the gears which slide into each other in the gear-boxes, and many others too numerous to mention. In fact, every industry, from implements of peace to weapons of war, invokes the help of a vast array of special machines which are designed and built for that industry alone.

Will the Machine Age Bring Less Drudgery and More Joy into the Worker's Life?

Whither is it all tending? Machines should lighten the load of human drudgery but as yet they appear to have increased it. The lot of a mere machine-minder is not an enviable one. His faculties are not exercised as they would be in the practice of a craft, but are stunted by lack of intellectual activities. He has become an automaton—nearly as mechanical as the machine he tends.

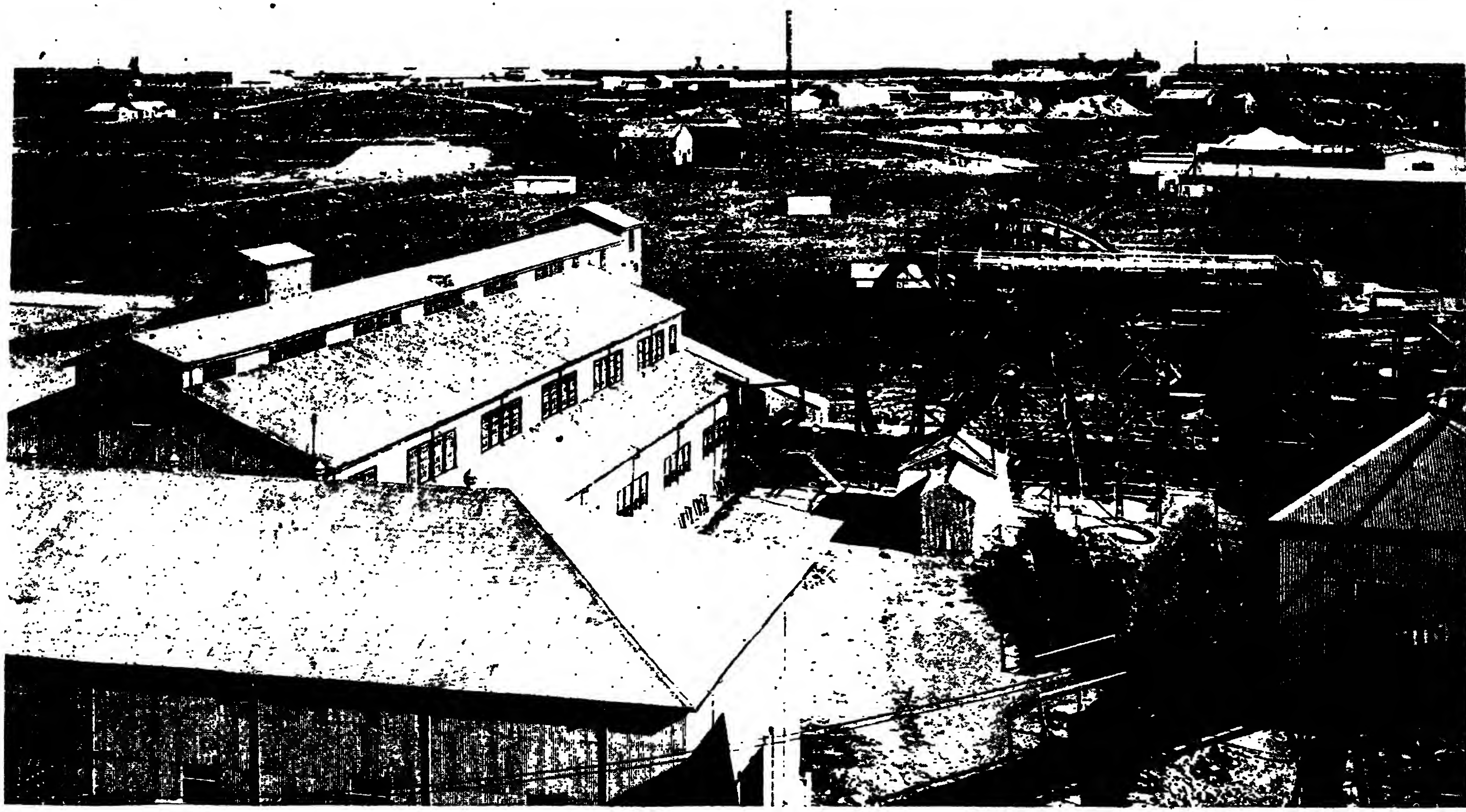
On the other hand, machinery has as yet given much employment to a growing population which would otherwise have been hard put to for a means of subsistence, but the whole subject is an extremely complex one, and we cannot forecast the ultimate issues. We know the arguments of the economists in favour of machinery, but we can conceive of a time when the evils of unemployment will become much more severe than at present, because the inroads of machinery always tend to increase at a higher ratio than the benefits conferred by it. We live in a period of transition, with its attendant ills. Ultimately, however, after much storm and stress, we hope and believe that the mission of machinery will be to uplift the labourers from a lot of grinding drudgery to a life of leisure and intellectual joy.

A MARVELLOUS MAKER OF WOOD BRICKS



The great demand for wood paving blocks has made a new industry, and an enormous amount of timber is used up yearly for this purpose. The timber is first sawn into strips or bars, and these are then fed into a huge machine such as is seen in these pictures. The machine cuts each bar into sixteen blocks and ejects them at the side. The lower picture shows the bars travelling up into the maw of the machine, and the top one shows the frame raised so that the bars and the resulting blocks are seen in progress.

A GENERAL VIEW OF A GOLDFIELD IN THE RICHEST GOLD AREA IN THE WORLD



The greatest factors of the future gold production of the Transvaal are to be found in the East Rand district, of which the surface is everywhere dotted with the structures of the various gold-mining companies, and the rocks below honeycombed by their workings

SYMBOLS OF PROSPERITY

The Astonishing Development of the Goldfields and Diamond Mines During the Last Fifty Years

THE QUEST OF THE PRECIOUS METALS

A Scythian traveller who visited Athens during the great age of Greece reported that the Greeks made constant use of pieces of gold and silver which they exchanged for commodities. "But," he added, "the only value of them seems to me to be that they make arithmetic and numeration more easy."

This Scythian had never seen money before. It was not used in Scythia, where goods were exchanged directly without the assistance of "pieces of gold and silver." He had a shrewd mind, though, for he saw at once what a great many find it very difficult to see, even after long use of money—that gold and silver do serve only as a method of rating values. Their own value is artificial. As David Hume expressed it in one of his essays: "Money is not, properly speaking, one of the subjects of commerce, but only the instrument which men have agreed upon to facilitate the exchange of one commodity for another."

It is true that gold is used for ornaments and dishes, for various kinds of small articles in personal use, in all sorts of ways by which vanity may be satisfied and the possession of wealth made evident. But if these were the only uses of gold it would not have given rise to a great industry. It is because the world has agreed to make it "an instrument for facilitating the exchange of one commodity for another" that its production has increased in the last quarter of a century to five times what it was in 1886.

In the earlier half of the 'eighties, the annual value of the output of gold was round about £18,000,000. In those days gold coins were scarce, even in Scotland, where greasy one-pound banknotes passed from pocket to pocket until they almost fell to pieces. In Italy, gold pieces were seldom seen. In Russia, few people outside the largest cities had ever handled one. Gold, in fact, was scarce, though nothing like so scarce as at the beginning of the nineteenth century, when the annual production was a little short of 600,000 ounces. By 1850 it had risen to nearly 6,500,000 ounces, and so it remained until the 'eighties.

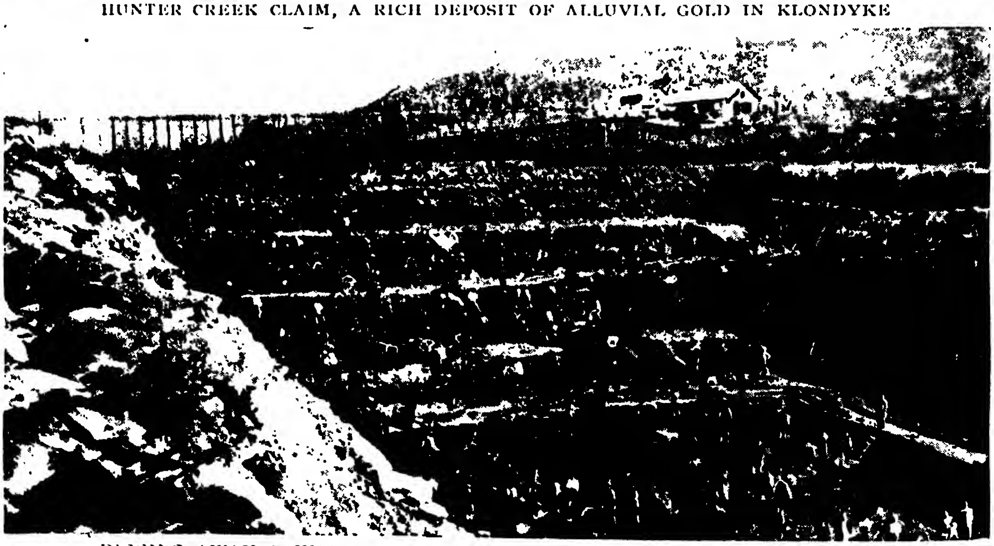
Then came the discovery of the immensely rich reef in the Witwatersrand district of South Africa, and the figures of production rose by rapid bounds. In 1890 the value of the year's output was reckoned at £23,000,000; in 1896 at £46,000,000. Ten years later it had doubled again, and stood at £82,000,000. In that year—1906—South Africa contributed to the value of £26,000,000. In 1908 the amount of gold produced all over the world was 21,529,300 ounces, and in 1910 the output of South Africa alone was valued at £32,000,000; and it is still on the increase.

Nor is it only in South Africa that more gold is being taken out of the earth. The production of Australasia and the United States has largely increased also; Russia, Mexico, and Canada contribute in a rising ratio; and in many parts of the world experienced mining experts are hunting for fresh sources of supply. The consequence is that the only two great countries which still make use of "small" paper money to any great extent are Russia and the United States. Even Italy, where not long ago coins were eagerly sought after in preference to the "notes"—worth ninepence, eighteenpence, and so on—is able to use the precious metal for her medium of exchange.

But this more common use of gold coins is not altogether an advantage. Already there are complaints that the increased production of gold has raised prices all round. To explain how this comes about would mean writing a treatise on Money, and that is far from being the purpose of this chapter.

GOLD MINING IN THE LONELY WILDS

HUNTER CREEK CLAIM, A RICH DEPOSIT OF ALLUVIAL GOLD IN KLONDYKE



DIGGING AWAY A HILLSIDE OF GOLD-BEARING ORE AT NAKATAMI, SIBERIA

The alluvial gold deposits of Siberia and the Klondyke have been the scenes of many valuable discoveries. For example, at the Hunter Creek Claim, in the Klondyke, for some time £300 worth of gold was found every day. The Nakatami mine of Siberia resembles a quarry.

WASHING WEALTH FROM THE SOIL

POWERFUL STREAMS OF WATER THAT WASH AWAY SOIL FROM GOLD IN BRITISH COLUMBIA

THE DARK ENTRANCE TO A MINE IN A MOUNTAIN SIDE IN ALASKA

In some places the surface soil is so rich in gold that it is simply washed by hydraulic sluicing. Great jets of water are played upon the soil, and the water washes the earth or gravel away, leaving the heavier gold grains behind. In other places the gold, known as "reef gold," is found disseminated among various rocks, whence it can be obtained only by arduous labour and costly machinery.

Briefly, however, it may be taken as a matter of general knowledge that the more there is of any commodity, the cheaper it becomes. This applies even to gold—although its price is kept up artificially by the fact that banks will, for raw gold, pay over its weight in gold currency. Therefore gold has become cheaper as the supply has increased —that is to say, the purchasing power of gold has become less.

The Great Power of the Gold-Mining Magnates of the Rand

There is, however, no prospect of any immediate check to the rate at which the stock of the world's gold is multiplied. An immense amount of capital is invested in gold-mines. An immense number of people are employed by the industry. Ingenious minds are continually at work devising means of raising more gold and cheapening the methods of extracting it from the ore. Towns, like Johannesburg, that have grown up as goldfield centres depend for the support of their populations upon the rate of production being maintained. Any attempt to restrict by Government regulations the amount of gold mined would be opposed by very powerful interests, and be doomed to fail.

Nowhere is the gold interest more powerful, nowhere are the methods of production more perfect, than on the Rand. All along the Ridge which shelters Johannesburg, and stretches for some fifty miles on either side of the city, the mines betray their presence by their shaft-gear, black against the sky, and by their shining, flat-topped hills of white dust, the "crushings" which have had the gold separated from them. As usual, the energies of man applied to getting richer have outraged Nature. Vanished is the quiet charm of the rolling and peaceful veld, with its willow-fringed pools to reflect the colours of the sunset, and farmhouses with belts of trees to hide the poverty of their architecture. Chimneys pour forth polluting smoke. Tin-hut villages abound, with all their unlovely accompaniments. Native compounds are seen, their corrugated iron walls topped by barbed wire entanglements.

The Gamble of Early Days that has Become an Immense Industry

Make friends with a mine manager, and he will show you the whole process by which masses of rock are fined down into "pigs" of gold. It is a process quite marvellous in its rapidity, its efficiency, its brilliant ingenuity. What a change from the clumsy methods of Red-shirted Jack, the 'Forty-niner! But, clumsy though they were, when compared with the scientific effectiveness of the mine machinery of to-day, the 'Forty-niners (those who joined the rush to the Australian goldfields in 1849) had more fun. Then it was a gamble, a lottery. Now it is an industry, organised with infinite care and calculated to turn out the same quantity each day, just as if it were a tool-works or a jam factory.

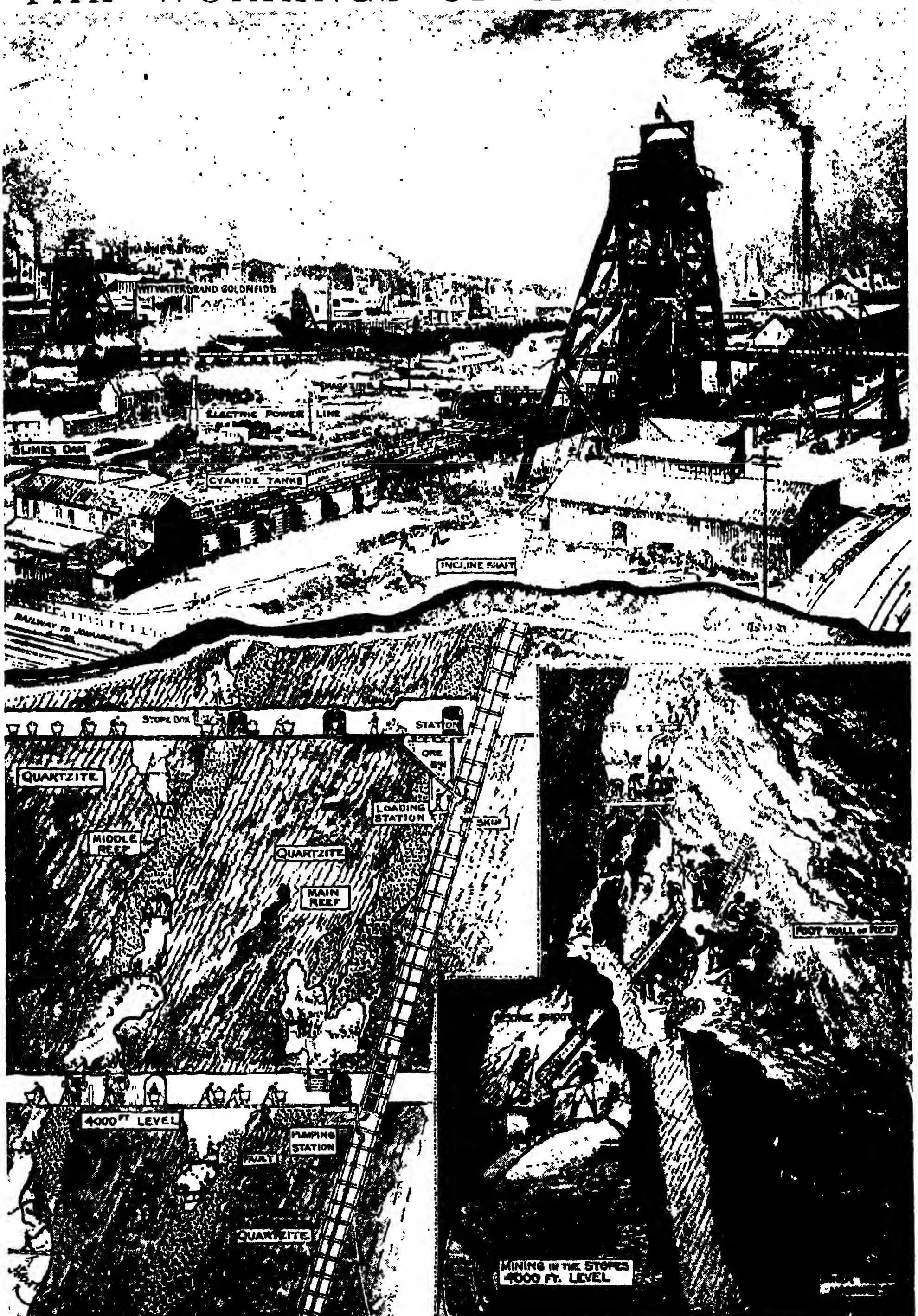
From the pit-head gear a cage of the familiar coal-mine pattern runs you down a couple of thousand feet almost before you have realised that you are off. Then you follow your guide through miles of passages cut in the rock and lighted by electricity. Every now and then a shout is heard, and round a corner comes a truck of ore, wheeled by shining black men, who grin cheerfully as they pass. Your feet splash in the water which has collected in pools on the uneven floor. Your head bumps with rhythmic regularity against the low roof. Fortunately, you were wise enough to accept the loan of a suit of overalls and a rough old cap. Otherwise your clothes would be ruined.

In the Depths of the Earth with the Men who Find Gold

At intervals along the passage are sloping cuts. These lead to the reef. Soon we come to one from which light and noises come. The rest have been dark and silent. Here they are working. We drop down on our hands and knees (if we are stout of build we must drop on our stomachs) and wriggle our way down the sloping cut. It is only about three feet high, so the fit is rather tight. The ground, too, is damp clay and loose slate, which slides away from under you. If the clay were not kept damp, miners' phthisis, which is caused by dust, would be far more prevalent than it is.

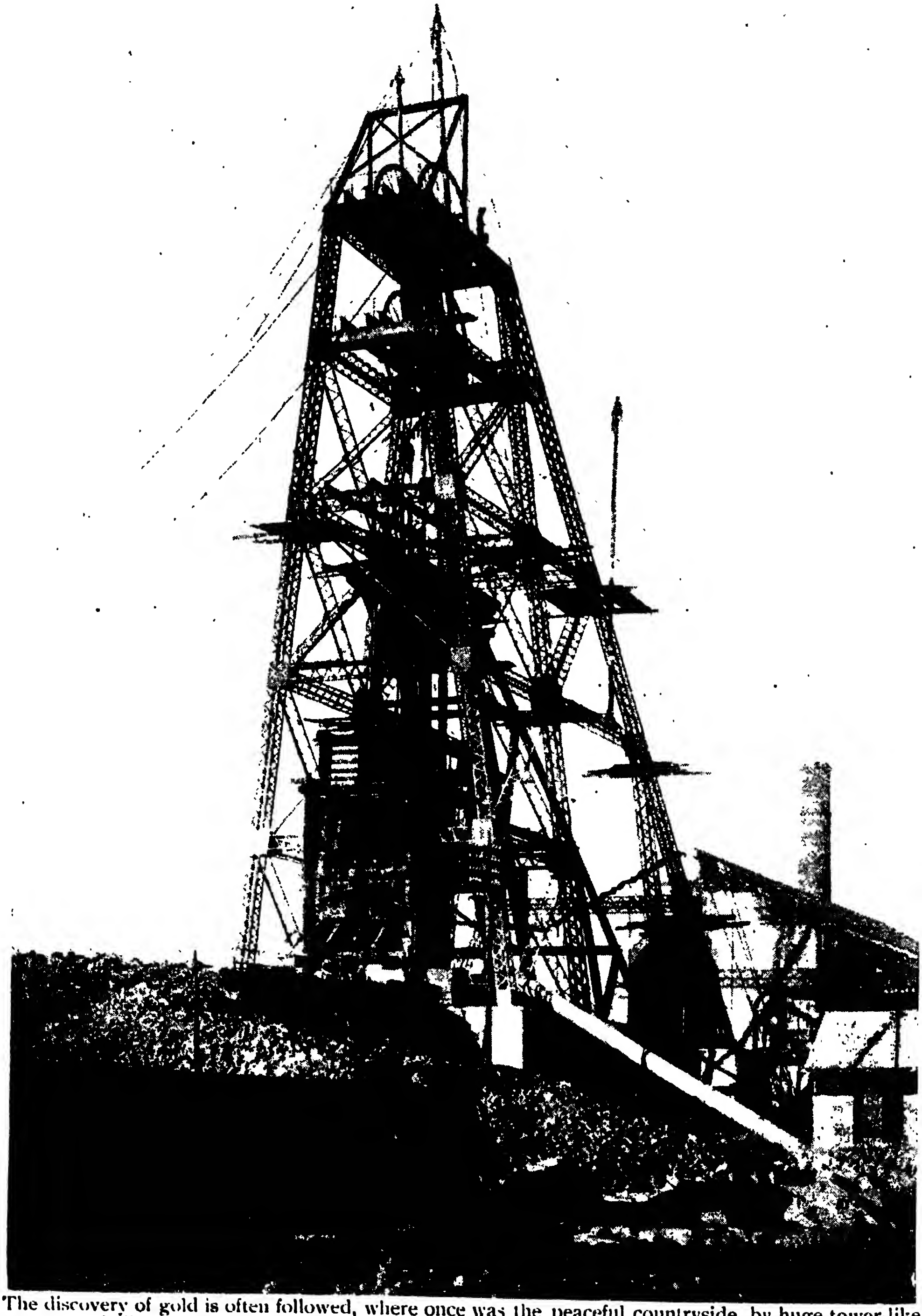
However, we need not wriggle far. Here are the Kaffirs at work boring holes for the dynamite cartridges. They bore them with drills held in their hands, and they also use mechanical drills. The hand-drilling natives earn about five pounds a month, which to them is wealth beyond their dreams. Their work would be terribly monotonous to a white man, but it just suits them; they hammer, hammer, hammer away, and do not think about it. When enough holes have been bored they will be charged and exploded. Down comes a mass of gold-bearing reef. This is cleared away by the men with the trucks, and dropped down to the bottom of the

THE WORKINGS OF A RAND MINE



The Witwatersrand Goldfields, popularly known as the Rand, stretch for about fifty miles around Johannesburg. The gold is found in a series of reefs, the lowest of which—the celebrated Main Reef—has given the Rand the position of the premier goldfield in the world. This Main Reef is mined to a depth of over 4000 feet. This picture shows a general view of a portion of the Rand, together with a sectional sketch through an incline shaft and the galleries that run from it.

THE LATTICE-WORK OF POWER AND WEALTH



The discovery of gold is often followed, where once was the peaceful countryside, by huge tower-like structures built over the shafts of the mines, with shining, flat-topped hills of white dust in the background, produced by "crushings," or the dividing of the rock containing the gold into small .and These structures are part of the machinery for lowering the miners and raising the ore.

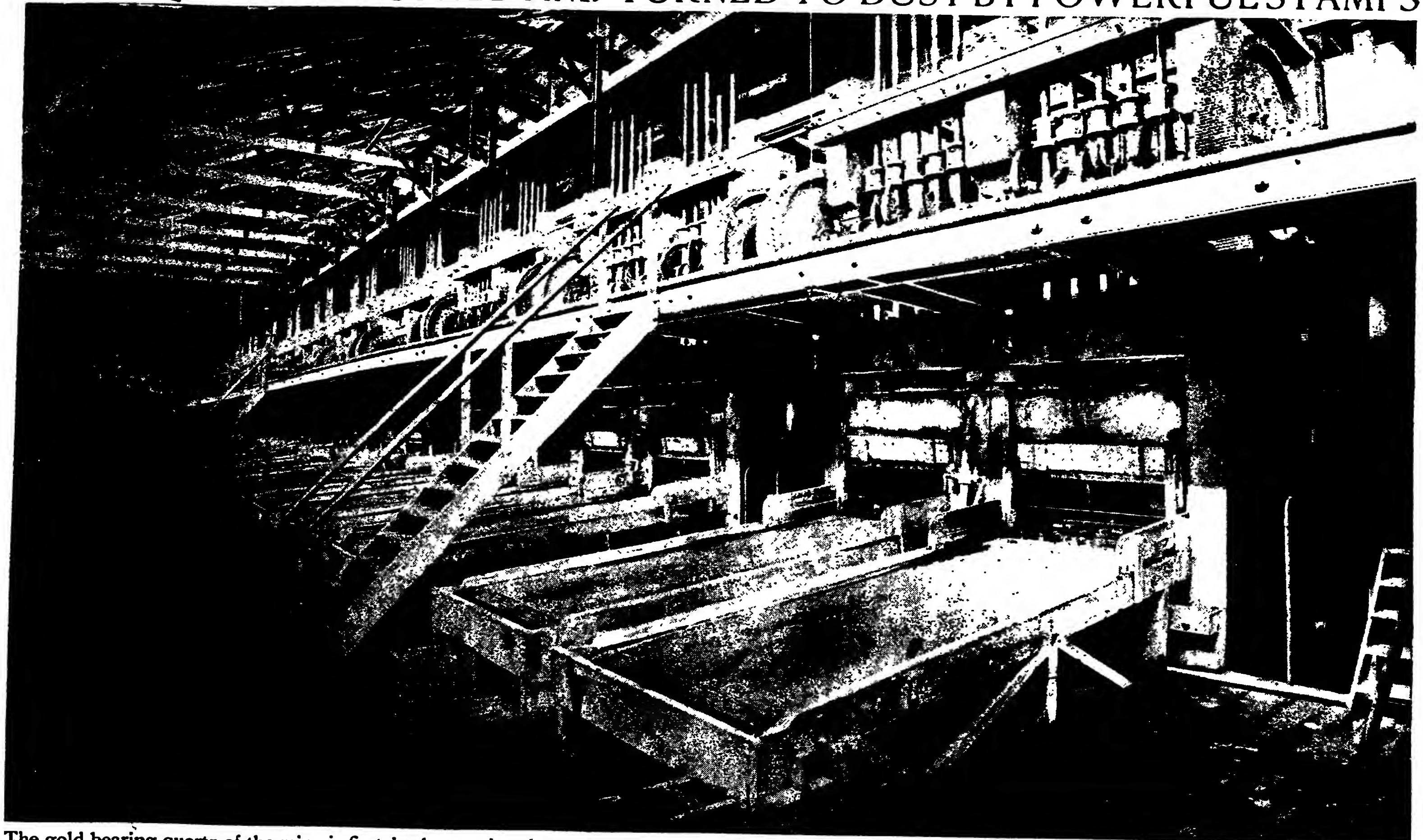
N THE HEART OF A GOLD MINE

A WINCH WORKED BY COMPRESSED AIR FOR HAULING TRUCKS IN A GALLERY

WORKERS WITH A PNEUMATIC DRILL THAT BORES INTO THE HARD ROCK

'he lower picture shows a "stope"—an excavation from which the quartz is being extracted either bove or below a level, or gallery, in a series of steps. Labour-saving rock-drills and winches are to-day worked by compressed air, which powerful engines force down pipes into the deepest levels.

GOLD QUARTZ CRUSHED AND TURNED TO DUST BY POWERFUL STAMPS



The gold-bearing quartz of the mine is first broken up into lumps, which are then crushed by the stamps shown at the upper end of the tables. The crushed rock is then washed down these tables, mercury being added from time to time to arrest the gold, with which it forms an amalgam.

mine. Thence a skip rushes it up an inclined plane to where the hoist awaits it. In the hoist it shoots up to the light, and is flung out with a roar and a rattle into the big shed where stands the sorting-table.

This is in the shape of a crescent. The Kaffir "boys"—all Kaffirs are "boys"—who do the sorting in South Africa stand inside it. They steadily separate the worthless rock from that which has gold in it, the latter being distinguished by its markings of milky white. This is thrown on to a moving band which takes it towards a hopper, and here a powerful pair of iron jaws await it. They open and shut with a horrid crunch. No rock is too hard for them. They reduce it all to a finely uniform size so that it can be dealt with by the "stamps."

The new kind of noise we hear now is made by the stamps —thud, thud, thud, like a hundred giants' feet coming down, not all together, as if they were tramping or marking time, but irregularly. You can hear them on a still night miles away. Thud, thud, thud, down comes their immense weight, over half a ton, stamping on the gravel and crushing the gold out of it. For the rock is gravel by this time. It has been further ground in a "tube mill," a rolling cylinder with very hard stones in it which carry further the process begun by the iron jaws. Finally, it is reduced by the stamps to sand.


GOLD MINERS DESCENDING A SHAFT IN INDIA

Here is the sand coming out mixed with water. It flows on to a table which is always in motion—a pulsator-table. This table is covered with mercury, and to the mercury adheres a large quantity of the gold which glistens bright among the sand. The gold and the mercury together form an amalgam; they are separated later by distillation. It was this amalgam which used to be stolen so freely. Hundreds of thousands of pounds were lost by thefts every year. Now robberies are less frequent. There is a heavy penalty for buying gold through any but a recognised channel, and the seller of stolen amalgam may be sent to prison for five years. There is still, however, a great deal of gold in the sand which has passed over the table. The mercury cannot catch it all. The sand, therefore—now known as "battery pulp" or tailings—is divided into three classes, according to its richness, and after that led away to the great vats of cyanide of potassium which are now a feature in all gold mines of any importance. In the vats it remains up to two weeks. Then the liquid is drawn off into tanks filled with zinc shavings. They look like tanks in an aquarium. The shavings might well be seaweed, and one half expects to see a fish's snout poke up amongst them. What happens in them is this: the gold in the solution drawn from the cyanide vats is attracted to the zinc and clings to it. How skilfully man uses for his purpose the attractions and repulsions between Nature's substances! In this way almost all the gold which escaped the mercury is detained by the zinc.

Now in a quiet warm room we can see the crucibles at work forcing the zinc and the mercury to give up their prey. Fire is the agent used. In goes the amalgam, in go the zinc shavings, and presently out flows a stream of liquid gold. It fills moulds, and soon becomes a series of ingots, which are taken off to the railway yard, loaded into special trucks, and sent down to the sea, thence to be carried to all parts of the world.

A very different process that from the popular notion of gold-mining, which still imagines "diggers" toiling in the hot sun and coming every now and then across a "nugget," a solid lump of precious metal that can be sold immediately for its weight in sovereigns. The only reality which comes near corresponding with that romantic conception is alluvial gold-seeking. Alluvial gold is gold which has been washed into river beds; the way this is usually collected is by "panning" the sand. Sometimes the deposits of gold are very rich

but they are soon exhausted when systematically attacked.

Another method of dealing with alluvial gold is "dry blowing," which is practised in Australia. The alluvial soil is sifted through sieves which let the sand and dust pass, but retain the nuggets. In the early days of Australian mining "dry blowers" became rich in a few weeks. One "digger" had his horse shod with shoes of gold. Others hung necklaces made of nuggets round the necks of barmaids. The notorious Lola Montez, the dancer, when she went to Ballarat between fifty and sixty years ago, was rewarded by showers of virgin gold as she stood bowing and smiling on the stage. The romance of gold-mining has always had rather a squalid side to it.

Even more than to gold-mining does a romantic interest attach to diamond-mining, and for the same reason. In each case the product is rare and costly. In each case the early methods of mining gave the adventurer plenty of scope, and enabled fortunes to be made very quickly by those who happened upon rich finds. But nowadays the search for diamonds, like the getting of gold, is no longer an adventure. It has become a business, a highly organised industry. The romance connected with it has evaporated altogether.

Nature's Marvellous Transformation from Wood to Coal, and from Coal to Diamonds

Sometimes diamonds are found in the beds of rivers, like alluvial gold. These river stones are of very fine quality, and sell for nearly double the price of other diamonds. But by far the greater quantity of the gems which glitter in women's hair, on their necks and their fingers, are obtained by mining India and Brazil used to be the chief sources of supply, but South Africa has, since diamonds were found there near Kimberley in the 'seventies, become by far the largest producer. Diamonds have been known and valued since very early times. Their name comes from a Greek word, "adamas," which meant "hard," and is still used in another English word, adamant. From adamant came diamant, then diamand, and so diamond.

It is, of course, the hardest stone we have, and is therefore used for cutting purposes as well as adornment. Nothing will cut a diamond, for instance, except a diamond. Nothing cuts glass so well, nothing drills porcelain so neatly; and the dentist will tell you that, when he uses a whirring instrument of torture for hollowing out a cavity, he is using a diamond on your tooth.

Diamonds are formed by volcanic pressure of an unimaginable force. They are the rich relations of common black coal. Charles Kingsley said once in a popular lecture: "We may consider the coal upon the fire as a middle term of a series of which the first is live wood, and the last diamond. We may indulge safely in the fancy that every diamond in the world has probably at some remote epoch formed part of a growing plant—a strange transformation, which will look to us more strange, more poetical, the more steadily we look at it."

The Precious Blue Ground in which the Diamonds are Formed

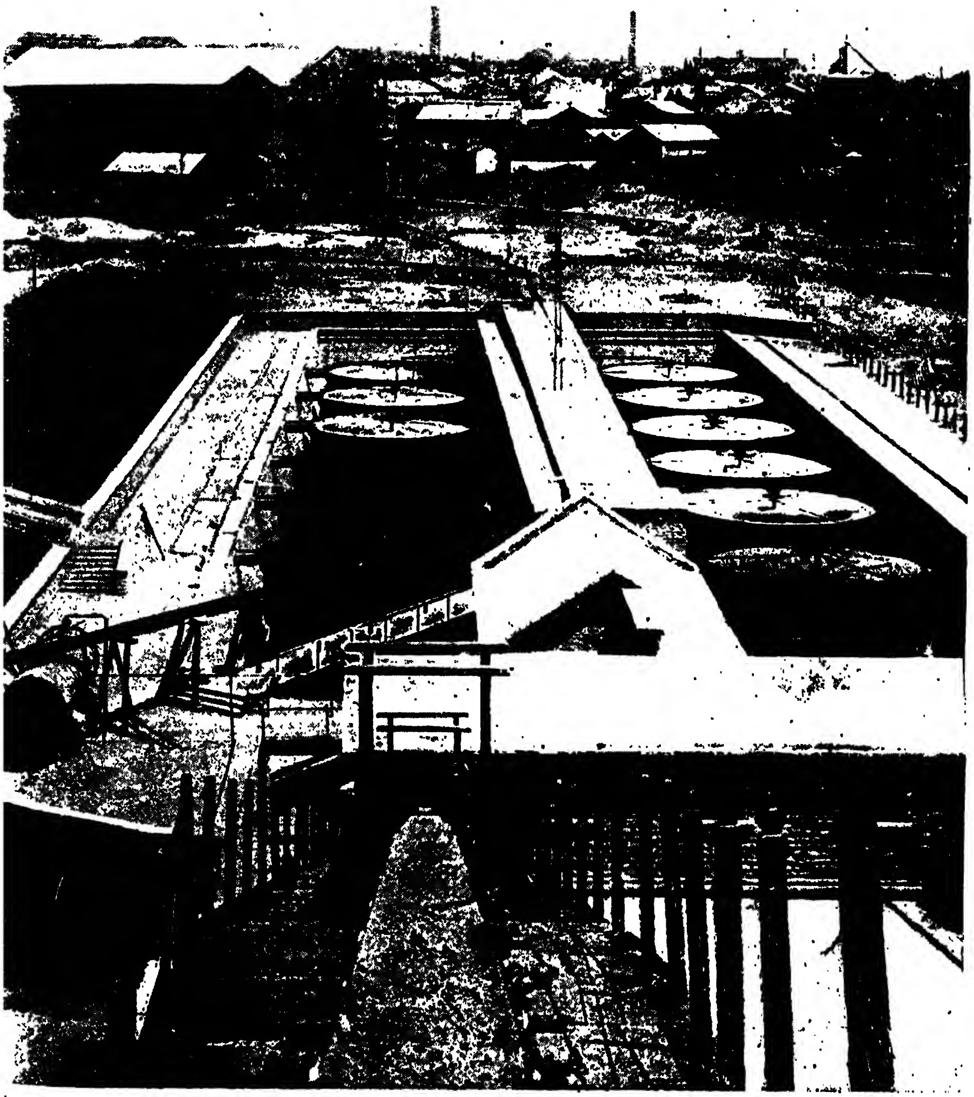
When they are not alluvial, diamonds are found in what is called "blue ground," a bluish-green soil, very heavy in character, which runs in "pipes," or columns, deep down vertically into the earth. This "blue ground" is mined by means of shafts sunk in the ordinary way, and then laid out on great open spaces of veld or prairie called "floors." These "floors" are naturally well guarded. Barbed wire entanglements surround them, sentinels with rifles pace round them all night. Here the "blue ground" remains for a long time, to be broken up and made friable by sun and rain. The old method was to crush it with mallets, but this was clumsy and expensive, and had to be abandoned.

It was found that the air and the weather had the same, and even a better, effect than the mallet. So it is simply spread out on the ground and left; the only treatment applied to it is that in some cases it is turned with steam ploughs. Sometimes it lies out for a year or more before it is ready to be dealt with. When that time comes it is loaded on to small trucks, and carried up an artificial hill, from the top of which it is dropped into the washing-pans.

The Distinction Between a Diamond in Its Bed and a Pebble Beside It

The pans revolve continually, and they are also provided with teeth, which crunch and grind the hard lumps. As you stand above them the noise is terrific. The wooden scaffolding trembles. You feel almost afraid of the monster which the ingenuity of man has created. It does its work thoroughly, and seems to enjoy it. From one pan to another the blue ground passes until the gravel where the diamonds are has been separated from the useless soil. For every hundred trucks of blue ground carried up the hill, only one truck of gravel is passed to the next process. The rest is waste; it has been washed and chewed away.

EXTRACTING THE GOLD FROM THE SAND



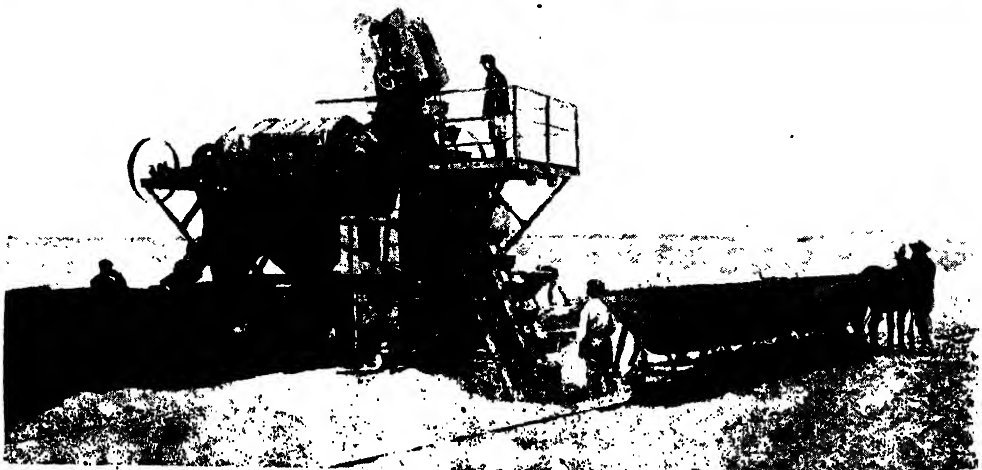
he amalgamating-tables do not remove all the gold from the crushed rock. After leaving the tables he sand is carried away from the room where the stamps are and out into the open air as shown in he front of this picture, and deposited in great vats containing cyanide of sodium, which removes the gold and forms a solution, from which the gold is afterwards recovered.

he photographs on these pages have been supplied by the Consolidated Gold Fields of South Africa, the Consolidated Main Reef Mines, Messrs John Taylor & Sons, Mr. Horace Nicholls, and the Editor of the "African World."

OLD AND NEW WAYS OF FINDING DIAMONDS

SEARCHING FOR DIAMONDS ON THE SOIL IN SOUTH-WEST AFRICA

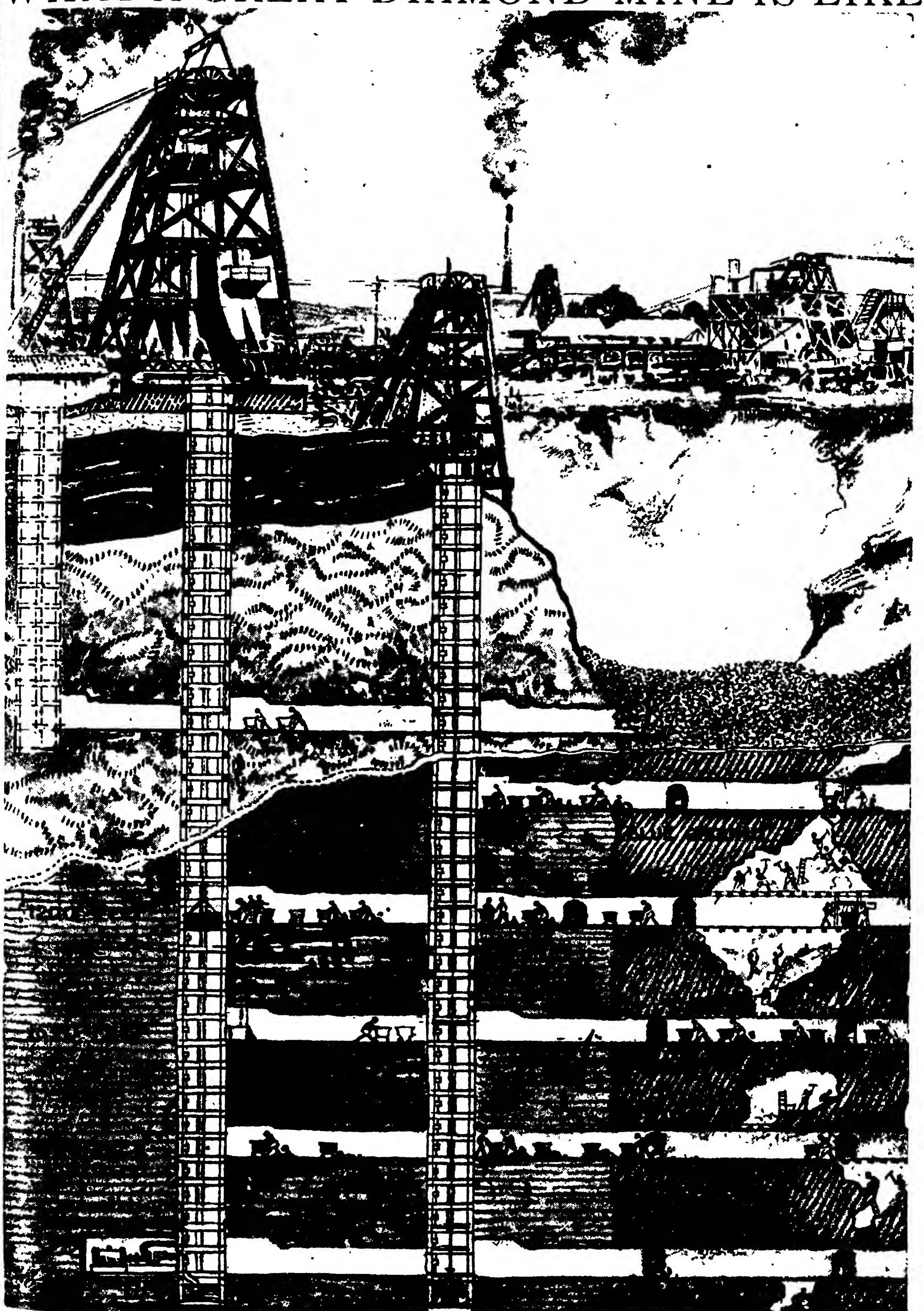
WASHING DIAMONDS OUT OF THE BLUE GROUND BY THE NEW VAAL RIVER



A MODERN MOTOR SIFTING-MACHINE AT WORK IN SOUTH-WEST AFRICA

Three methods of securing and separating diamonds from the soil are shown in these illustrations. In the top picture is shown the most primitive method of searching for diamonds in parts of South-West Africa; and, as a contrast, the bottom picture shows a modern diamond motor sifting-machine

WHAT A GREAT DIAMOND MINE IS LIKE



There is a vast difference between the methods of the early diamond-miners and the modern mining companies. Labour-saving machinery on a gigantic scale is now employed. The "ground" is transferred in trucks to the shaft, where it is tipped into skips holding six truck-loads. These are hoisted to the surface, where their contents are poured into trucks, drawn away in a continuous procession by an endless wire rope to the vast disintegrating floors.

Follow the truck of gravel, and you will see how the diamonds in it are picked out from among the worthless stones. Take up a handful, and your unskilled eye cannot distinguish between them. For the diamond in its natural state is not the sparkling gem which you see in the jeweller's window The sparkle only comes when it is "cut" in Antwerp or in Amsterdam. Here in the truck it looks very much like any ordinary stone. The expert sees that it is not rounded, however; it is eight-sided. Also, it is heavier than the ordinary stones.

The Endless Band that Drops Stones and Diamonds into Water

Machinery is required, therefore, to collect the heavier stones from the gravel and let the lighter ones pass away. The machine is a marvel of invention. It is called a "pulsator." Already we have seen a pulsator-table at work in the shed at the gold-mine. This is on the same principle—the principle of the beating pulse. The truck turns out the gravel into a hopper, an endless band catches it, carries it aloft, sifts it, grades the stones into six sizes with perfect accuracy, then drops them down into troughs six feet long and about two feet wide. With the stones water flows in, and the whole mass moves incessantly with uncanny jerks. Put your hand into the water and on the stones. It feels as if some animal were underneath, breathing in quick, unquiet gasps. Jerk, jerk, jerk, all the heavier stones are slipping down to the bottom. All the lighter ones are being drifted by the water to the end of the trough, where they are washed away. At the bottom is a grating. The heavier ones fall through.

But not all these heavier ones are diamonds. The hundred trucks of blue ground were reduced to one truck of gravel, and now the one truck has been divided into five parts, one of heavier stones, four of lighter, valueless pebbles. Yet there is still another stage to be gone through before the diamonds alone are left. Many of the heavier stones are pebbles also. These have to be weeded out; and the medium which man calls in to assist him in detecting and turning out the impostors is—grease.

The Shining Slab that Keeps the Diamonds and Lets the Pebbles Go

A slab shining with grease is moving to and fro. At the upper end the stones are dribbled on to it. The grease discriminates nicely between the weight of the diamonds and the weight of the pebbles. The former it holds; the latter it allows the water which runs over the slab to carry away. All the stones that are sticking to the grease are diamonds—dark, glistening, eight-sided diamonds, as beautiful to some eyes, when they have been dried and polished up a little, as the glistening cut stones are in ring, or necklace, or tiara.

This slab, however, lets some of the smaller diamonds slip by. So the stones which are washed off here are gathered up and dribbled on to a second slab. And even those which are rejected by this second slab are sometimes examined by Kaffir "boys" in case the slabs should not be doing their work carefully enough. Out in the sun there is a heap of stones on a sack. Black men are looking at handfuls of them. They would spot a diamond at once if they saw one. But they are not finding any in that lot. The grease has allowed none to escape from its clinging embrace. So closely does it cling that the diamonds are not picked out of it by hand, as one would suppose.

The Precious Medley that is Poured Into the Boiling Cauldron

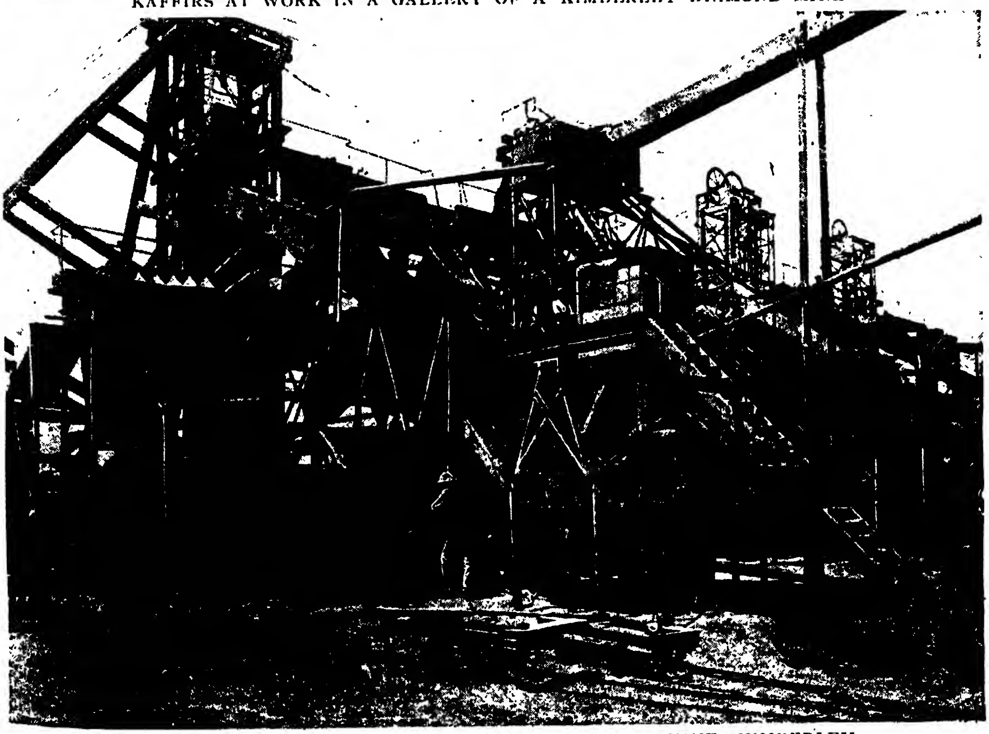
The whole of this extraordinary mess is scraped up, grease and stones together, and dropped into a pot. This pot goes into a cauldron of boiling water; it turns round and round until the grease is all washed away. Now the pot contains only diamonds, unless by accident there have got into it, as there often do, a few heavy pebbles which are of no value. Up to now, the separation, the testing, has all been done by specific gravity, so there is room for some doubtful stones. The next, and the final, process is to sort out the true from the false by hand.

This is done in a room full of light. It has tall windows. The glare is unpleasant. Why, you wonder, do they not work in a cool, half-darkness, with the blinds down? Then it dawns upon you that a great deal of light is necessary, both for seeing the difference between diamonds and pebbles, and also—this is equally important—to prevent any of the men who sit at the sorting-table from stealing any of the stones.

They are all black men, except the overseer. Their table is white, without a speck or stain. They work quickly, manipulating the stones with long knives. The white overseer sits all day and watches them. They are conscious always of his vigilant eye. Even if they did steal any of the diamonds, they would find it much harder now than it used to be to dispose of them. Buyers, as well as sellers, are punished when illicit diamond-buying is found out.

TOILING IN THE DIAMOND MINES AT KIMBERLEY

KAFFIRS AT WORK IN A GALLERY OF A KIMBERLEY DIAMOND MINE



THE WASHING PLANT OF THE DE BEERS DIAMOND MINE, KIMBERLEY

In the upper picture of the interior of a tunnel of a diamond-mine the miners can be seen at work with hydraulic drills boring the quartz, which is being removed by the negroes. For every hundred trucks of blue ground sent up to the washing-pans, only one truck of gravel is passed on to the next process.

"I.D.B." is the short name for it in Kimberley; in the old days fortunes were made by those who made it a regular practice.

All kinds of tricks, some amusing, some disgusting, were resorted to by diamond thieves. A favourite plan was to send them out of South Africa in religious books. A hole was cut in the middle of the pages; the diamonds were slipped in here; and the book, closed up again, looked quite innocent. To get them out of the mine-offices Kaffirs used to swallow them.

The Ways of the Clever Diamond Thieves of South Africa

One scoundrel had as many as seven hundred and fifty pounds' worth inside him in the year 1895. They used also to cut holes in their legs, and conceal diamonds in the wounds. Heavy penalties had to be imposed, therefore, upon any person dealing in diamonds, except through licensed dealers. Three years' imprisonment is the term that can be inflicted. This has had its effect. I.D.B., nowadays, has become rare.

At the office in Kimberley, where the diamonds are kept until the special railway van used for their conveyance carries them away, precautions are naturally taken against robbery. No one can visit this part of the De Beers building without a permit. No one, even when this permit has been obtained, can obtain entrance until a little shutter in the iron door has been opened and an eye has looked out to see if the visitor's appearance is satisfactory. But, once inside, you are free of the place so long as you obey the injunction on all the walls: "Visitors must not touch."

The Captivating Charm of the Diamond in Its Translucent Depths

Here men casually turn out tin boxes with thousands of pounds' worth of diamonds. They are so used to them that they handle them like nuts or beads. But they never seem to grow hardened to the beauty of the finest cut stones. They take up an exquisitely cut "pink" or yellow gem with marvellous colour in its translucent depths. Their eyes soften. They gaze at it with tender pride. Certainly no one has any idea of the charm of the diamond who has only seen it in the jewellers' shops.

The cutting of diamonds is chiefly done in Antwerp and in Amsterdam, though attempts are being made to create competition in London and in New York. It is a trade which requires exceptional skill, and is kept in a small number of hands. In Amsterdam there are about 15,000 people employed altogether in the various processes; in Antwerp, only 4500. The wages paid average between two and three pounds a week. Not a high average, yet losses are very rare. The honesty of the workpeople who handle these immensely valuable stones is proverbial.

About half the weight of a stone is lost in the process of making it ready to wear. "Rose diamonds" are cut from the eight-sided stones, the "rose" referring to the style, not to the colour. "Brilliants" are cut from diamonds with curvilinear faces. Very large stones can be divided. The largest white diamond known was taken out of the Premier Mine, near Pretoria, and presented to King Edward the Seventh. It was called the Cullinan, and weighed 3025 carats—about 1½ lbs. Its size was 4 inches long by 2½ inches broad, and 1⅓ inches high.

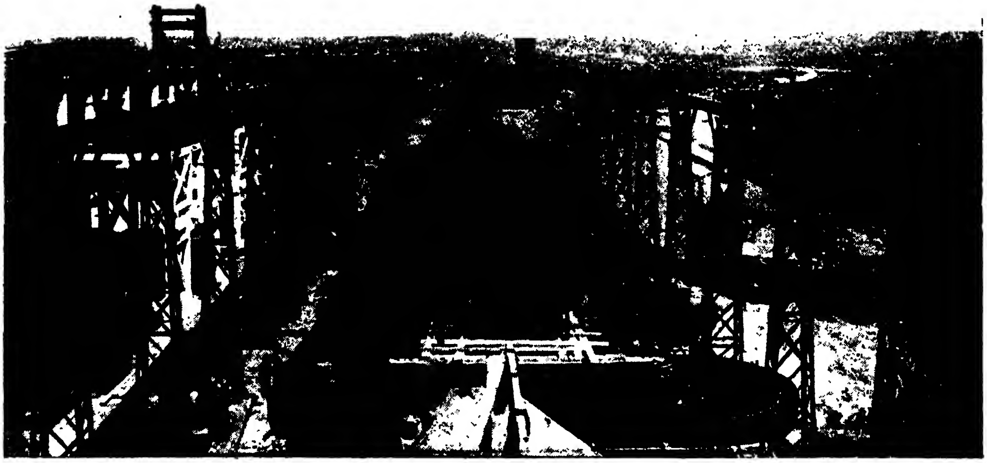
Naturally, the cutting of such a stone is a matter which requires much thought. It must be made the most of. Nothing must be lost. The planning of the Cullinan partition took two months. Another nine were occupied in cutting it into nine large gems and a number of small brilliants, which are all worn by the Queen of England at great State ceremonies.

Why the Price of Diamonds is a Sign of a Country's Prosperity

In order to keep the price of diamonds fairly regular, the South African companies have an agreement by which the output is controlled so that the market may never be glutted. Dealers also work more or less in harmony to the same end. So long as the world's finance is prosperous, the demand for precious stones keeps up. When there comes a crisis, it falls off: people have less money to spend on personal adornment. The financial collapse of 1907 in the United States was very bad for the diamond industry. The production had to be checked; only gradually could the old rate of output be resumed.

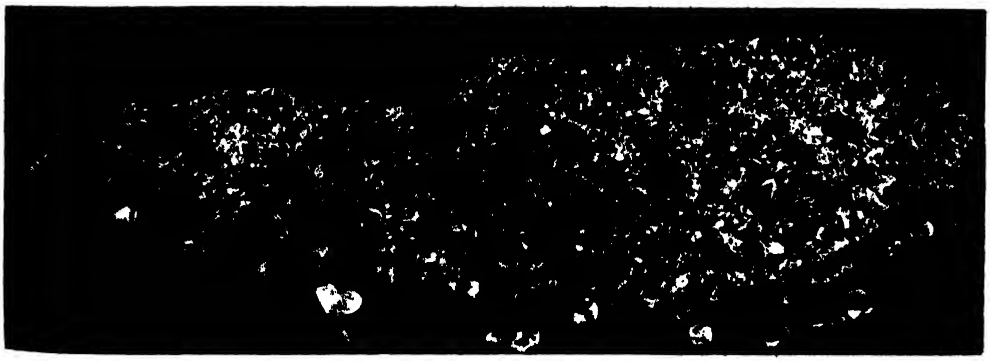
The rate at which a country buys diamonds is a test of its prosperity. A diamond has few commercial uses; it is the purest luxury. When people are making money quickly they do not buy books or pictures. They do not even spend money on fine furniture and house decoration. These come at a later stage. Their first instinct is to purchase something that proclaims their riches. That is why diamonds sell in such vast numbers, why diamond production has become so large an industry, and why the fortunes made in it have been so many and so vast.

A DAY'S PRODUCE IN A DIAMOND MINE



CIRCULAR WASHING-PANS IN WHICH THE SOFT EARTH IS REMOVED FROM THE MINERALS & DIAMONDS

PULSATOR TABLES ON WHICH THE DIAMONDS ARE FURTHER SEPARATED OUT



A HEAP OF DIAMONDS SECURED IN ONE DAY'S WORKING

The "blue ground" is exposed to the action of the weather and harrowed by steam ploughs. It is then fed through perforated cylinders into the washing-pans or shallow cylindrical troughs in which the diamonds and other heavy minerals are swept to the rim by revolving toothed arms, while the lighter stuff escapes. The heavy minerals then pass over sloping tables known as pulsators, where they are shaken to and fro under a stream of water, which effects a second concentration.

THE HARDEST WORK DONE IN THE WORLD

"THE PUDDLERS," A VIGOROUS REPRESENTATION OF THE HARDEST WORK DONE IN THE WORLD

"THE SPIRIT OF VULCAN," THE PATRON GOD OF WORKERS IN METALS—BY THE LATE EDWIN ABBEY, R.A.

The upper picture is by M. Meunier, and the lower one is reproduced by permission of Messrs. Curtis & Cameron

A YEAR'S BRITISH WEALTH

A Survey of the Produce of the Fields and Factories and Mines of the United Kingdom

THE ENERGY OF 45 MILLIONS OF PEOPLE

THE primary object of British trade and industry is, or should be, to give plenty to our enormous population. We conceive the daily labours of our forty-five millions of people as exerted to furnish forth a great store of material commodities and personal services to be shared up between us.

The census returns show us that, out of our forty-five millions, some twenty millions, including adult men and women, young persons, and even children, are "engaged in occupations." Their tasks are many and varied beyond description. A large section is engaged in the construction, renewal, or repair of artificial ways, underways, and conduits, dwelling places and recreation grounds, buildings for Government, instruction or amusement, factories and mills for production, offices, warehouses, and retail shops for direction, storage, and distribution. All this goes to build up the material framework of our society; and its nature and formation have much to do, through the compelling influence of environment, with the health and the character of us all. The labour upon the solid foundations of our civilisation, together with the watering and lighting and heating and sewering incidental to its maintenance, occupies one of our largest industrial groups.

Other large sections of workers raise or procure food and materials for men and for industries, or they manufacture clothing, implements, furnishings, utensils, books, or periodicals for the maintenance of comfort and the amenities of life. Others manufacture for manufacturers, providing them with the engines, machinery, plant, tools, etc., necessary for economic output. Others, again, construct vehicles or railways or ships for the conveyance or transport of people and commodities. No small number are engaged in the making or repairing of warships or munitions of war; and, finally, many of our workers, forming no small proportion of many branches of these varied occupations, are concerned with making goods for export. Important as all these material and directly productive labours are, it is interesting to observe that less than one-half of the twenty millions gainfully employed are at work in them. The remaining workers, about eleven millions of people, in round numbers, are engaged in private direction, or public government, or transport, or wholesale or retail buying and selling, or finance, or employ themselves in contributing to the amusement, instruction, healing, or other service, of their fellows.

A commodity is not really useful, as we saw at the beginning, until it is taken to the place where it is needed. For that reason, it would be a profound error to regard as "non-producers" the eleven millions of occupied persons not directly engaged in producing material commodities. There are amongst them, for example, the railway and other transport workers, who have as much to do with material production as a man who works a lathe, or lays bricks, or carries a ladle in an iron foundry. These, by moving fuel or materials to seats of production, or by transporting finished commodities from their places of origin to the people who desire to use them, add to the real value of the articles they transport. They are as much engaged in "producing" these articles as though they worked in the mills or factories.

A railway man is equally a producer when he helps to convey an artisan to his work, or a clerk to his office.

Similar considerations apply, at least under present conditions of civilisation, to merchants, agents, brokers, bankers, and other commercial workers. The work of these agents provides an ample supply of materials where they are needed, and

secures the useful distribution of products after they are made. Indeed, under present circumstances, it is true that it is far easier to make boots by modern machinery than it is to market the boots after they are made. The banker, again, by giving credit, and conducting the machinery of exchange between buyers and sellers, takes a real and essential part in production. The great host of retail traders, by conveniently placing stores of commodities at the disposal of those who need them, may also claim to add to the value of the articles which they sell. The doctor, engaged in his onerous and dangerous mission of healing, produces in effect more than he consumes. Finally, the lawyer who interprets legislation or conducts a dispute for a litigant, the policeman who helps to guard life or property, or the actor or singer who cheers the life of a direct or indirect producer, may have as much effect upon material production as a man who figures in the census returns as an actual manufacturer of commodities.

This is not to say that the eleven millions of employed persons who are not direct producers of material things do not include a considerable proportion of middle-men and hangers-on of industry and commerce, whose economic position it would be hard to justify. Here we are not concerned to study in detail this important point. Suffice it to say that the continuous processes of industrial and commercial organisation and of social experiment, as they reveal the existence of unnecessary or wasteful units of work or service, will gradually eliminate the factors which are economically undesirable. If such processes were not gradual in their operation, they would be cruel in the extreme; and the student of social forces must ever have regard to the necessity either for slow transition or for the mitigation of hardship in cases of unavoidably rapid transition. It is probable that the importance of these considerations will increase in the twentieth century, owing to the fact that industrial and commercial changes are taking effect much more rapidly than of old.

We have said that some twenty millions of our population are employed for gain. We shall do well to remember that many millions more, not employed for gain, are useful producers. The multitudes of working mothers, especially in that great majority of households where there is no domestic servant, are material producers in the most exact sense. The woman cooking a dinner, or cleaning a house, or making or mending a garment, is one of the nation's manufacturers. Indeed, she is usually a much more necessary and important national factor than a woman who, working in a mill, is registered by the census as a producer. The poor woman's apple-pie is no less a " manufacture " because we cannot measure its value or include it in a statistical return.

When all these varied and important considerations are taken into account, it remains an interesting and suggestive fact that, apart from the domestic productions not made in return for wages, the great mass of commodities which is the basis of material wealth is the work of some eight million wage-earners officered by about one million salaried persons.

This domestic material production does not express the entire bulk of commodities —food, materials, and manufactures— which the United Kingdom enjoys. Part of the British material production is exported and exchanged for foods, materials, and manufactures brought from oversea. Again, other material commodities come to be imported in exchange, not for material exports, but for services rendered to persons oversea. Amongst these services transport by shipping and financial assistance rank highest. These points we shall examine in detail hereafter.

AMOUNTS CLEARED AT THE CHIEF ENGLISH BANKERS' CLEARING HOUSES—IN MILLIONS STERLING

YEAR	London	Birmingham	Liverpool	Manchester	Newcastle	Bristol	Leeds	Leicester	TOTAL
	Million £	Million £	Million £	Million £	Million £	Million £	Million £	Million £	Million £
1896	7,575	50	121	194	55	23	12	10	8,040
1898	8,097	54	129	204	66	26	15	12	8,603
1900	8,960	53	168	249	86	29	16	12	9,573
1902	10,029	50	166	235	81	31	16	11	10,625
1904	10,564	53	198	249	77	31	18	11	11,201
1906	12,711	58	189	294	55	31	21	11	13,370
1908	12,120	56	177	289	46	31	20	12	12,751
1910	14,659	61	222	308	49	32	22	13	15,366

A YEAR'S PRODUCTION IN THE CHIEF BRITISH INDUSTRIES

INDUSTRY	A Factory Value of Output	B Cost of Materials	C Value added to Materials	D No. of Persons Employed
FACTORY VALUE OVER £100,000,000:	£	£	£	
Coal Mining	123,245,000	16,881,000	106,364,000	840,280
Cotton Factories	176,940,000	129,999,000	46,941,000	572,869
Iron and Steel Smelting, Rolling, and Founding	105,597,000	74,649,000	30,948,000	262,225
Engineering	101,599,000	52,174,000	49,425,000	455,561
FACTORY VALUE £50,000,000 TO £100,000,000:				
Woollen Factories	70,331,000	50,879,000	19,452,000	257,017
Flour Milling	65,255,000	58,887,000	6,368,000	36,207
Brewing and Malting	67,110,000	25,970,000	41,140,000	85,222
Clothing	64,803,000	37,468,000	27,335,000	442,217
Building	87,967,000	45,013,000	42,954,000	513,961
FACTORY VALUE £20,000,000 TO £50,000,000:				
Shipbuilding	48,110,000	27,943,000	20,167,000	209,615
Chemicals	23,447,000	13,983,000	9,464,000	51,088
Railway Construction	34,703,000	17,600,000	17,103,000	241,526
Bread and Biscuits	38,902,000	27,305,000	11,597,000	110,304
Tobacco	23,799,000	17,988,000	5,811,000	37,456
Boots and Shoes	22,959,000	13,994,000	8,965,000	126,564
Printing and Bookbinding	37,920,000	13,940,000	23,980,000	218,449
Gas	31,607,000	14,329,000	17,278,000	83,531
Jute, Linen, and Hemp	31,798,000	22,460,000	9,338,000	153,464
Total over £20,000,000	£1,156,092,000	£661,462,000	£494,630,000	4,697,556
FACTORY VALUE UNDER £20,000,000: Including, in millions of £, Coke 10; Cycles and Motors, 11; Leather, 18; Paper, 13; Lace, 10; Copper and Brass Smelting, 17; Soap and Candles, 12; Hardware, 15; Bleaching and Dyeing, 18; Cocoa and Confectionery, 16; Sugar, 12	600,908,000	383,538,000	217,370,000	2,238,444
GRAND TOTAL	£1,757,000,000	£1,045,000,000	£712,000,000	6,936,000

When we endeavour to form an idea of the extent and value of the home trade of the United Kingdom we find ourselves involved in insuperable difficulties. For, owing to the multitude and complexity of the various transactions which are built up as a gigantic superstructure upon the basis of a definite production of material wealth, it is difficult even to hazard a guess as to the total value of these transactions.

Let us consider what at first sight would appear to be a very simple case, and select a simple material commodity made in a British factory. Here is a packet of soap, which cost a few pence to manufacture. Simple as it is considered as a crude chemical production, and small as is its value, it becomes the subject of widely varied employments; and by the time it is ultimately purchased it carries values added to it by those employments. Making the soap is an exceedingly easy matter. The main activities of the soap-maker are centred on the task of persuading people to buy the soap he has made. Commerce, rather than industry, necessarily occupies his thoughts. He finds it necessary to invent a novel or striking trade name for his ware, and to defend it against all comers. He employs artists to embellish the name, and literary men to write about the name. He draws up striking advertising posters, and pays large sums for the right to exhibit them on hoardings, on walls, in fields, or at railway stations. He buys space in newspapers and periodicals in which to proclaim the goodness of his soap. He has to employ clerks and others to check all these things from printing to publication. He establishes a large staff of travellers, who, each in his district, keeps constantly in touch with shopkeepers,

obtaining orders, in spite of other travellers working for other soap-makers. The soap itself is boxed and wrapped, and accompanied by printed matter, or even by coupons the accumulation of which secures for the purchaser a prize of some sort, in which case another department of activity is set up to purchase and distribute prizes according to the scheme of distribution.

The Complex Trade Built Up on a Simple Commodity

When all this is considered it will be realised that the "trade" built upon the simple commodity soap is a most complex thing, leading to the creation of varied employments, and causing commercial book entries impossible to measure in gross. There are cases simpler than this, and cases much more complex, but few indeed are the commodities which in our modern civilisation do not become the subject and cause of multifarious transactions and employments.

The more fully we investigate this complexity, the more we are impressed with the gigantic bulk of the total transactions which make up the internal commerce of the country. While we cannot measure the total, or disentangle financial or merely speculative transactions from those relating to sales of commodities or services, we have in the records published by the Bankers' Clearing Houses a means of arriving at some conception of its magnitude. In order to facilitate the settlement between banks of cheques and other instruments of exchange, the bankers do not directly call upon each other to honour their obligations, but send all the cheques, bills, etc., which are paid to them to a clearing house, which sets off the liabilities of each bank against the others, so that all the bankers maintaining the clearing office have merely to pay each other balances.

The Vast Extent of the Business Dealt With at the Clearing Houses

Thus we get, in the record of the clearances, a clue to the amount of business done in all but very small transactions, for all trade in this country is transacted by cheque or other paper, save only the retail trade purchases of the poor, and the trifling purchases of the well-to-do.

We give at the bottom of page 872 the returns published by the London and some provincial bankers' clearing houses. The chief of these is the London institution, which clears a great deal of country as well as of town paper. It will be seen that the totals are stupendous, representing amount which it is almost vain to endeavour to grasp.

The figures are given in millions; and we see that in 1910 the London and seven provincial clearing houses deal with over 15,000 million pounds sterling—£15,366,000,000—of cheques, bills of exchange, etc. A large part of this figure relates, of course, to finance; and the increase shown in the period of fifteen years reviewed in the table must by no means be taken to represent a corresponding increase in trade. Improved trade has, of course, played its part, but the huge transactions connected with finance have a tendency to obscure the trade figures. The figures are not concerned with home transactions alone, it should also be remembered; the figures of 1910, for example, were swollen by very large issues of new capital in the nature of foreign and colonial loans and the rubber boom. When all this is taken into account there remains the proof of a gigantic erection of trade and financial transactions set up on a comparatively small basis of material production.

The Ways in which We are Now Able to Measure Home Trade

By investigating the railway returns we can ascertain the progress of the receipts by the railway companies on account of transporting minerals and goods about the country, but here, again, we get little assistance in measuring home trade; we are only provided with a valuable clue as to the progress of trade. Thus we know that between 1903 and 1910 the minerals conveyed on British railways rose from 344,000,000 tons to 405,000,000 tons, and that the general merchandise conveyed rose from 100,000,000 tons to 109,000,000 tons. Here is evidence of a very large and growing conveyance of commodities, but the figures relate to the carriage of imports and exports as well as of internal commerce.

Fortunately, we have in a recent official inquiry of the first importance some exceedingly valuable information as to the value of the British material output. Under the Census of Production Act, the Board of Trade made a detailed investigation, for the year 1907, into the production of British mines, quarries, mills, factories, and workshops. The Board was empowered by Parliament to collect the information compulsorily; and for the first time in the United Kingdom we are able to form an accurate idea of the value of that output,

The powers given to the Board of Trade did not enable them to obtain compulsorily information as to the capital employed or wages paid. These omissions were unfortunate; and it is earnestly to be hoped that Parliament will soon see the advisability of measuring the progress of the nation in these respects. Merely to take the results of the census as they are, however, they are certainly of the highest national value and importance.

The broad results of the census inquiry, which were published in nine lengthy official reports between 1909 and 1911, are summarised on page 873. The figures relate to every sort and kind of extractive and productive industry, except agriculture. The work of all our mines, quarries, mills, factories, and workshops is summed up in the totals

British mining and manufacturing is done by rather less than seven million people, of whom rather less than 500,000 are salaried persons, and rather more than and about 6,500,000 wage-earners—men, women, boys, and girls. Of the 6,500,000, about 1,000,000 are boys and girls under eighteen years of age. So that the number of adult or nearly adult wage-earners employed in British mining and manufacturing is about 5,500,000.

"THE WORKERS OF ENGLAND"

These people work upon our native coal and other materials, and upon stuff imported from abroad, to produce goods for the home and export market. We cannot by the census distinguish the distribution of their labour as between the call for goods at home and the call for goods abroad, but we shall be able presently to form an idea of it. What the table gives is the sum of the value of the result of their labours.

It will be seen that column A gives the factory value of the output, or wholesale selling price. This comes out at the very large figure, for all the industries, of £1,757,000,000. But this figure by no means stands for the true value of the production of the industries taken as a whole, because it obviously contains a large amount of duplication. For example, the iron first appears as iron, and next appears as an engine or a ship, its value being counted twice, or even more than twice. This element of duplication is got rid of by column B, which shows for each industry what it purchased in the form of materials—*e.g.*, the shipbuilder shows the value of the iron or steel which he bought from the iron and steel manufacturer. Then, by deducting column B from column A we get column C, which shows the value added to the materials used by the various industries, so that the total of this column, £712,000,000, is a "Net Output." It means that the persons employed shown in column D added £712,000,000 of value to the materials they worked upon in the year 1907.

Before we proceed to ascertain what is the true total value of British productive industry taken as a whole, let us survey the list of industries shown in the table.

The industries with over £100,000,000 each of gross factory value are coal, cotton, iron and steel, and engineering. These great staples between them employ over two million people, or about one-third of all those engaged in industrial productive work. They thus bulk enormously in British trade, and are, in point of fact, its backbone.

The second group of industries named on page 873 range from £50,000,000 to £100,000,000 in factory value. They are five in number—woollens and worsteds, milling, brewing and malting, clothing and millinery, and building and contracting. These between them employ over 1,300,000 persons. The chief of them are woollens, clothing, and building. Milling occupies a high place in point of production value, because of the high ratio of the value of

the grain used to the value of the gross output. The value added to the materials, however, is comparatively small, little more than £6,000,000, and the persons employed number only 36,000. Brewing, again, has a fictitious importance in the table, because the factory value of the product includes the duty.

Building, on the other hand, is not covered entirely by the figure given, as a certain amount of building work is included in other industry groups—*e.g.*, railway construction.

The other chief British productive industries are shown in the third group, ranging in factory value from £20,000,000 to £50,000,000. The first of these is shipbuilding, which has an output worth £48,000,000, and employs over 200,000 people. The others are the chemical manufacture, railway construction, bread and biscuit making, tobacco manufacturing, boot and shoe making, printing and bookbinding, gas-making, and the jute, linen, and hemp manufactures. It will be seen that nearly a quarter of a million persons are at work in the construction and repair of our railways.

Another very large and important group of employers are the printers and bookbinders, which include newspaper printers. Over two hundred thousand persons are now employed in the output of books, newspapers, and periodicals, and the factory value of these things is nearly £38,000,000. It should be observed that the value of the output of the tobacco trade is swollen by the dutiable character of the material.

Taking these three groups together, the industries with productions of over £20,000,000 each are seen to be few in number, but they employ nearly 4,700,000 persons out of the total of less than 7,000,000 persons engaged in industrial pursuits.

The remaining productive industries with factory values less than £20,000,000 employ just over 2,200,000 people. The chief of them are the coke manufacture, cycle and motor making, leather manufacture (not including the making of leather goods), paper-making, the lace trade, copper and brass smelting, the brass trades, soap-making, the hardware trade, bleaching and dyeing, cocoa and confectionery making, sugar-refining, tinplate-making, the hosiery manufacture, paint and colour making, iron and steel tube making, the wire manufacture, the oil trade, china and earthenware manufacture, brick-making, railway carriage and waggon building, distilling, aerated-water making, plate and jewellery manufacture, cabinet-making, indiarubber work, and miscellaneous quarrying.

Government and municipal as well as private work are included in the table. It covers, for example, the building and repair of warships, the manufacturing at Woolwich Arsenal, and the output of Army clothing factories.

Let us now reconsider the net output of £712,000,000 shown in column C of the industrial output table, and see what has to be added to it or deducted from it in order to arrive at the *total value of the actual goods of all sorts won by British work in a year.*

We start with this £712,000,000 of net output of industry, all duplication having been eliminated by each trade deducting the value of the materials which it uses.

The first addition to make is on account of agriculture, which employs over 2,000,000 people in the United Kingdom. The Board of Agriculture have in preparation an official estimate based upon a voluntary census of British agriculture, but unfortunately this is not available. We have to use, therefore, the careful estimate which was made for the Royal Agricultural Society by Mr. R. H. Rew. This estimate was made in 1895, and was as in the following table, the whole of the United Kingdom being considered as one farm, and all duplication as far as possible avoided.

ESTIMATED VALUE OF AGRICULTURAL PRODUCE IN THE UNITED KINGDOM

	£
Crops of all kinds	63,600,000
Meat, including poultry and rabbits	74,300,000
Horses and other live-stock	6,500,000
Dairy produce, eggs, wool, etc.	49,400,000
Total	£193,800,000

Since this estimate was made, production has varied in some particulars, and prices have risen. We shall probably not exaggerate the value of agricultural produce in 1907 if we take it in round figures at £200,000,000. Adding this to the net industrial output, we get £912,000,000.

We have now to consider how this total is supplemented and depleted by imports and exports. We have to add to it the net imports into the United Kingdom for home consumption of foods, materials, and manufactures, and to subtract from it our exports of British-made foods, materials, and manufactures. For 1907, the necessary factors are as shown in the table on the next page.

A YEAR'S BRITISH EXTERNAL COMMERCE

GOODS	Imports for Home Consumption in 1907*	Exports of British Goods in 1907
	£	£
Food and tobacco	235,100,000	22,700,000
Raw materials	188,700,000	55,000,000
Manufactures	127,900,000	342,000,000
Miscellaneous	2,200,000	6,300,000
Totals	£553,900,000	£426,000,000

* These figures show *net* imports—total imports less those re-exported in the merchant trade, and not retained for consumption in the United Kingdom.

This information enables us to complete our inquiry. To the total of £912,000,000 which we have arrived at as the sum of British internal material production in industry and agriculture, we have now to add the £553,900,000 of imports for home consumption, and to deduct the £426,000,000 exports of British produce, the imports being an addition to the store of commodities shared up in the country in a year, and the exports a diminution of that store. The exports go out, of course, in order to earn imports, and the imports in the above table come in to pay for the exports of goods and for various services rendered to foreigners and British colonists. The £912,000,000, plus imports £554,000,000, and minus exports of £426,000,000, are raised to £1,040,000,000. To make the matter quite clear, we set out all the factors in a simple statement.

A YEAR'S BRITISH PRODUCTION, PLUS EARNINGS FROM ABROAD

	£
1. Manufactures and minerals produced in the United Kingdom. Net value of output (from Column C of table on page 873)	**712,000,000**
2. Add estimate of value of British agricultural production (p. 876)	**200,000,000**
	912,000,000
3. Add imports into United Kingdom for home consumption...	**554,000,000**
	1,466,000,000
4. Subtract exports of British goods	**426,000,000**
5. Result — one year's gain of material wealth	**£1,040,000,000**

So we arrive at a reliable estimate of the wholesale value of what the British people gain in material commodities for consumption in the home trade in a year. All elements of duplication are avoided. We have before us the solid basis of native material production, and material earnings from abroad, upon which is built that great superstructure of "trade" to which we have referred. We have found it possible to measure satisfactorily the basis of the trade, although we cannot measure the trade itself. We see also very clearly from the facts relating to bankers' clearances, examined on page 872, that the dealings connected with the processes of distributing and sharing up the £1,040,000,000 worth of material commodities are enormous as compared with the commodities themselves.

The investigation we have made is not only of fundamental importance to the proper understanding of British home trade and British external trade, but has a most significant relation to the problems of sociology. A year's British gain of material wealth being £1,040,000,000, and the population being 45,000,000, we see that the average yearly share of each member of the population amounts to little more than £23. This at once disposes of the popular conception that an equal distribution of existing wealth production would make everybody comfortably well off.

Such an equal distribution, it is clear from the facts, would not give everyone more than a very modest standard of comfort. It becomes apparent that the solution of the problem of poverty depends not only upon a better distribution of wealth, but upon the production of a larger amount of material wealth to distribute. A great and really plentiful production, utilising a larger part of the labour force of the nation's mental and manual workers, and exercising that larger part upon the most economic industrial plants and equipments, appears to be a condition precedent to any considerable improvement in social standards. The unity of the sciences is again brought home to us by these vitally important considerations, and only by properly considering these things can we hope to promote human welfare.

It is to be feared that many of the best-intentioned efforts of statesmen, and much of the devoted work of students of society, are vitiated by lack of acquaintance with such basic factors of trade as we have studied in these pages. The understanding of industrial and trading operations is essential to the safe guidance of the sociologist; and it is impossible to promote the welfare of those who labour without comprehension of the nature, results, and deficiencies of our present organisation for work.

THEODORA OF BYZANTIUM

THE DANCING-GIRL WHO BECAME AN EMPRESS

By VAL PRINSEP, R.A.

WOMAN'S PLACE IN THE SUN

The National Folly of Repressing the Intelligence and Individuality of the Mothers of the Race

FREEDOM OF WOMEN IN THE EARLY WORLD

IN many ways, life at Athens in the days of Pericles was the summit of human achievement, a summit never attained before or since that time. No doubt we have improved in certain directions upon the achievements of the Greeks, but what we have gained does not make up for what we have lost. The Greek mind at its best remains an ideal, to which now we are only gradually approaching. The civilisation created by the Athenians shows, in a small but perfect way, some of the lovely and harmonious lines on which, we hope, our own disordered civilisation will develop.

The portentous thing about this miraculous period in Athenian history is that the work was done practically without any aid whatever from women. More than this, it was carried out by men who deprived woman of every social, political, and public right, and imprisoned her in her home.

"Aspire only to those virtues that are peculiar to your sex, and think it your greatest praise not to be talked of one way or another," said Pericles, in his famous speech to the Athenian women. Women were only servants in the house of their father or husband, and from youth to old age they were regarded as minors. They were not allowed to mingle in the society of men; they were not educated to take part in intellectual conversation; and their lives were chiefly spent indoors, tending to the children, spinning and baking, and doing domestic work. The Athenian woman, save in her capacity as the mother of children, was despised by some of the best minds of Greece. "A slave," said Aristotle, "is entirely deprived of the faculty of deliberation; children possess it, but it is incomplete and imperfect; and the woman has it, but only in a feeble and inefficacious way."

The freemen of the city which thus contemned its women were scarcely more numerous than the inhabitants of Guildford at the present day. Yet they broke the power of Persia at Marathon and Salamis; they created many of the chief arts, established free institutions, and practically created European civilisation. "Nothing lives and moves in the modern world," said Sir Henry Maine, "which is not Greek in origin." How are we to reconcile the splendidly effectual work of the Athenians with the deplorable position in which their women were kept? Does it not look as though men have no need whatever of women, except as mothers of their children?

And we have a more recent example than ancient Athens of the apparent uselessness of the woman in civilised society. Ever since Marathon the European races have felt themselves to be generally superior to the peoples of Asia. Here and there the Asiatic has occasionally beaten us back by force of arms, but, on the whole, we have seemed to excel him in both the arts of war and the arts of civilisation. A few years ago, however, Japan suddenly showed herself to be as well organised and as powerful as a great European Power. Far more suddenly than ancient Greece, she acquired the culture of the advanced nations around her, transformed it into something original, rearranged her national life, and sprang forth full-armed, enlightened, progressive, and expansive. Yet, while this wonderful development was taking place, the Japanese woman remained in a position remarkably similar to that occupied by the Athenian woman.

Trained from her cradle to habits of docile subjection, she took no part whatever in the magnificent work of revolution done by the Japanese man. Sweet, pliant, colourless, without any ideas of will-power of her own, the Japanese woman passes from the rule of her father to the rule of her

husband and her husband's parents. She is a silent, laborious little housekeeper, from whom nothing more is asked than that she should bear her husband children—sons, if possible—and prepare his meals and look after his house and his clothes. She has practically no rights. If her husband ill-treats her, she must still meet him with a smiling face, and he is able to divorce her on various slight pretexts. And now that the industrial revolution has begun to affect Japan, the lot of the Japanese woman of the lower classes has become more deplorable. She has often to work for the greater part of the day in a factory at a low wage, and still manage to keep her home clean and cheerful.

How War has been the Great Enemy of Women in Social Life

It is very doubtful if the change from barbarism to civilisation improved the social position of woman. We have already pointed out that it benefited her in other ways, by helping to make the marriage bond more stable, by mitigating the incessant drudgery which shortened her life and human life generally, and by leaving her free to pursue the gentler and more domestic arts. On the other hand, the organisation of civilised society was mainly effected by war. The development of agriculture, in which woman originally played so important a part, resulted in certain races of mankind taking to a permanently settled way of life. The idea of landed property, whether held by single families or in commonalty by the clan, introduced a constant source of strife into the agricultural state. The individual passion of greed was born, and the sword was fiercely used by wealthy land-owners against their weaker neighbours. Certainly one of the earliest civilisations of which we have any record—that of Egypt—was founded by slaughter and usurpation. First we meet tribes of farmers continually at war with each other; and when they are at last united into a nation under a single ruler by a series of conquests carried out by the clans of the Thebaid, we find that all the machinery of despotism has been created.

The Tradition of Equality of the Sexes Upheld in the Earliest Ages

It is at this stage that the degradation of woman begins. Happily, in the very earliest civilisations, woman managed to retain somewhat of her position of helpmate to man. In Egypt, and still more in Babylonia, the status of women was higher than in many later civilisations. Traditions of the economic equality of the sexes were too recent to lose their efficacy, especially as there was no older nation at hand to give a bad example to the newly settled state.

Early Babylonia is quite extraordinary for the freedom allowed to its women. Their partnership was much valued by the men they married, and a distinct industrial position was maintained by spinsters. They formed themselves into large co-operative societies, under religious sanction, with vows of chastity. Unlike Christian nuns, they were free mistresses of their time and their labour. They lived where they would, and worked at what they liked, protected by their society as long as they kept their vows and paid their dues. Among the Hittites of Asia Minor, women had a similar high position and economic liberty, as they did also down to Greek times in backward Lycia. Agriculture and industry represent brains and perseverance; and wherever these two qualities had been long enough dominant at the dawn of civilisation to prevail against strength and animal courage, woman succeeded in preserving somewhat of her social and legal freedom, even though man entirely controlled the political system he had built up.

Man, Undomesticated by War, Drives Woman into the Seclusion of the Home

But as civilisations increased in number and in power, the sword became more powerful than the plough. The great kings took to keeping standing armies, first to defend their subjects, and then to extend their dominions. Small, peaceful, farming races were destroyed, and the warrior, bred to violence and rapine, became the master of society. Woman then began to fall, as she fell in Christendom during the fierce, brutal, feudal era. When civilised warfare became general, the work woman had done in domesticating man and attaching him to the soil was undone.

Agriculture produced an abundant and regular supply of food. This led, on the one hand, to over-population and expansion into new territories, often, no doubt, by main force. And, on the other hand, the comparative luxury of the farming nations excited the cupidity of neighbouring tribes of hardy, semi-nomadic shepherds and cattle and horse breeders. Man again became a hunter—a hunter of men—and the civilisations woman had founded by the arts of peace were now maintained by the arts of war.

Driven by the sword from the fields she had taught men to till, woman fled to the shelter of the house. There henceforth she remained, first under the loving protection

and then under the dominion, of the men of her family. Her position seems to have been aggravated by the fact that a series of successful invasions of pastoral tribes everywhere re-introduced into the fabric of civilisation the older patriarchal form of family government. This type of family was developed almost wholly by men under the conditions of pastoral life, where the economic value of women was slighter than in the higher stage of agriculture. Man domesticated, bred, and guarded the milk-giving, flesh-giving animals, and found children almost as much help to him as women; so, in this state of culture he tended to confine his wife, or wives, to the task of keeping house for him and bearing him useful children.

The Jews are a remarkable example of a pastoral, patriarchal race which won, wholly by means of the sword, a civilisation which it did not understand. It invaded a fertile, agricultural land, and took over the novel arts of agriculture, but retained its old patriarchal customs. When the Jew settled to tilling the soil, a great deal of the work fell on the woman, but she was allowed none of the freedom of the women of the early, original agricultural states. The misfortune that befell the Jewish woman, through the survival of pastoral laws in a more advanced society, affected for the worse the lot of the European woman thousands of years afterwards.

China and India seem also to be instances of the survival of the hard, tyrannical, patriarchal form of government in a civilised society developed from a later agricultural settlement. Compared with the Egyptians and Babylonians, the Chinese and Hindoos are late arrivals in the world of civilisation; and, like some other laggard races, they made their women pay the price for their backwardness. "Day and night must women be held by their protectors in a state of dependence," runs the law of Manu, the earliest and rather mythical legislator of the Hindoos. "A bride should only be a shadow and an echo in her husband's house," says an old classic Chinese writer. In an ancient Chinese book which still serves as an authority on education, it is said: "On reaching the age of ten years, daughters must never be allowed to go out of the house. They must be taught to be amiable, to

WOMEN OF SIENA REBUILDING ITS WALLS

Though woman is regarded as the weaker vessel, she has sometimes played an heroic part in defending her country, as the women of Siena did by helping to rebuild and defend the breaches in the walls of their city when it was attacked in 1553.

speak gracefully, to spin flax, to work silk, and to sew. At the age of twenty, they must be married." The life of a Chinese girl of the wealthier class is still directed by this ruling. Early in childhood she is secluded in the house, her mind and her imagination are starved, and her will-power is broken. She is an extraordinary example of the great power of education. All her individuality is taken from her, and she is transformed into the most passive human creature in the world.

The Broken Souls of the Women of China, the Most Passive Creatures in the World

"Heaven," say the Chinese, "has given woman modesty and innocence for the good of the family and the welfare of the children; and to man has been given the strength of body and soul to govern her."

Thus the woman in the most ancient of existing civilisations is allowed no personal and individual life. She exists wholly for the sake of her family and her children. Only in her old age does she win a little honour, if she is the mother of men. The Chinese say: "The mother happiest in regard to her daughters is she who has had only sons." The ingenuity with which the men of China have broken the souls of their women, and moulded them into quiet, sweet, docile slaves, is almost satanic in its cleverness. And here, again, might seems to be right.

In spite of the fact that they have exercised over the mothers of their race a moral, intellectual, and physical tyranny, extraordinary alike in its scope and its duration, the Chinese have for thousands of years survived all manner of revolutions and invasions, increased enormously in population, invented many arts and industries, and grown, on the whole, into a sober, peaceful, hard working, and intelligent nation.

How the Emancipated Women of Greece Lost Their Way

With the exception of the earliest agricultural states, hardly any ancient civilised race in the days of its power promoted the social and political equality of the sexes. The peoples of Europe scarcely treated their women better than the peoples of Asia. As is well known, the Hindoos form a branch of the European family; and when they invaded India they had a barbaric culture similar to that of the primitive Greeks and Romans, Teutons and Celts. So, originally, the position of the Hindoo woman was fairly high; but when her nation became civilised she gradually sank almost as low as the Chinese woman, and at the present day she remains on the same humble level as her sisters in China.

The Greek woman fell in the same way when her race invaded Greece, except among a few late-coming warlike tribes, like the Spartans, who held for military purposes to many of the traditions of their old barbaric way of life. What the Greeks were like in their semi-civilised days we know fairly well from the works of Homer. The Greek woman then had not lost her freedom. In the days of Pericles, however, she was only a household slave, suffering, if we may believe Euripides, from neurotic disorders, and chafing against the bars of her prison house. When she managed to emancipate herself, in the days when the Greek spirit was broken and weakened, she did not set a very good example. Neurotic, capricious, and greedy for excitement, she occasionally worked her way by intrigue to positions of power and glory; and there, like Cleopatra—who was a Greek woman, and not an Egyptian—she ruined the nation she undertook to govern.

The Dignity Attained by the Strong and Wise Action of the Mothers of Rome

The emancipated women of Greece were well known in Rome. They became the stock figures of Roman comedy; and the hatred, anger, and contempt which they excited told heavily against the Roman woman. The Romans arrived at civilisation by the ordinary way of agriculture. They were a race of warlike farmers, fighting among themselves, fighting with their neighbours, and fighting with the world, and always fighting for land. What they won by means of the sword they retained by means of the plough. So long as they remained militant agriculturists, the Roman woman preserved a certain independence of spirit. The laws were against her, subjecting her entirely to the father of the family; but economic conditions favoured her in the agricultural days, and, like most farmers' wives of a capable sort, she had as much strength of character as her husband. She was like the Boer woman of the present day—a strong, managing, industrious body, too busy to attend to matters of state, but as eager and as active as her husband in looking after the farm. Yet her social life was always much freer than that of the Athenian woman, and at times she was a wholesale force in the state. Not being locked all her life within the four walls of a house, she developed a sense of national duty. The result was that in

A TYPE OF NOBLE WOMANHOOD

Although the Maid of Orleans is here shown captive in the hands of her enemies, she had proved that the world still responded to the call of noble womanhood, made familiar to the mediæval world by the pictures of the Mother and Child. This figure of Joan of Arc is taken from a fine painting by Mr. Roland Wheelwright, and is reproduced by permission of the Autotype Fine Art Company.

times of grave peril to the community she often displayed a remarkable patriotism. Some legal rights were allowed her under the Emperor Claudius, and in the age of Justinian and Theodora her position in the Empire became one of great personal and proprietary independence.

It is doubtful if the Roman woman was much indebted to the Christian Church for this victory over the traditions of pagan Rome. She appears to have won it partly through her own force of character, but mainly through the growth of finer feelings and larger ideas in Roman civilisation itself.

Early Christianity Less Favourable to Women than Roman Law had been

We are apt to overlook the fact that there was a natural progress in humanity and justice among the Romans, which, though merged at last in the general teaching of Christianity, was European in origin. This fact is clearly brought out by the remarkable conflict between late Roman law and the canon law of the Christian Church in regard to the personal rights of women.

Under canon law, the wife was again subjected to the will of the husband. Here we arrive at the point at which the traditions of the patriarchal régime, preserved by the Jews, began to affect for the worse the position of the European woman. There is nothing in the teaching of Christ which makes in any way for the subjection of woman. Quite the contrary. A divine foolishness, a strength in weakness, before which the power and the cunning of the world fade and are discomfited: such are the qualities of the Christian spirit as expressed in the actual words and the actual example of Jesus. And these qualities are surely found more often in women than in men. The Christianity of Christ and the progress of Roman thought might have concurred in producing a social and legal equality of the sexes, but a new factor arose when St. Paul intervened.

The Bad Effect of St. Paul's Jewish Attitude Towards Women

Paul began as a Pharisee. He belonged to the straitest sect of the Jews, and held to the traditions of the patriarchal era, preserved in the Mosaic institutions. We have already seen that under the patriarchal customs the Jewish woman had little or no personal rights. She was subjected to her husband, so that she could not make a vow without his consent. A man could even sell his daughter into bondage, as is allowed in modern China and Japan. In short, the women of Israel occupied a position simila to that into which other Oriental wome have fallen. "The badness of men," say the writer of Ecclesiasticus, "is better tha the goodness of a woman."

Such was the force of the Jewish patri archal tradition that Maimonides, the grea Jew of the Middle Ages, who was in man ways the forerunner of the modern move ment, held that woman should be kept un educated and confined to the care of th house. So it is not surprising to find tha St. Paul took a rather Jewish and Orienta view of the position. And perhaps in fram ing rules for the Gentiles he was influence by the ancient customs of the Athenians.

However this may be, St. Paul un doubtedly threw the whole weight of hi authority against the woman; and his pre judices were to a considerable extent em bodied in the canon law of the Christia Church. In modern times in England, Mil ton became the impassioned advocate of th Pauline view of the subjection of woman and it is probable that the ideas on th matter contained in "Paradise Lost," supported as they are by many texts i the Bible, have had some directing powe over the course of English, Scottish, an American thought. "The expositors of th canon law," said Sir Henry Maine, "hav deeply injured civilisation."

The Curious Decline of Woman's Power in the Freedom-loving North

We have now arrived at a very interestin problem. As an actual fact, the Europea woman—or rather the woman of th Northern European races who built them selves into nations on the ruins of th Roman Empire—has for centuries occupie a high position in society. Yet everything apparently, has been against her. Most o the traditions of the older civilisation wer opposed to her; the canon law assigne a very humble place to her in society, an many of the Fathers of the Church, who wer the spiritual legislators of Christendom regarded the daughters of Eve as a malig influence in human life. Moreover, th European woman of the new order belonge to a horde of fierce, ignorant, and barbari fighting men, who overturned the culture o Greece and Rome, and threw the greate part of the ancient world into a welter o dark, ferocious anarchy, delaying the ad vance of civilisation for a thousand years.

One new fine thing, however, the Norther barbarians introduced into the civilise world which they swiftly ruined and slowl built up again. They brought with the

a higher ideal of woman than the Roman, Jew, and ancient Athenian possessed. Rising directly from a semi-agricultural state of society, in which the wife was more the helpmate than the servant of the husband, they gave the mothers of their race a nobler place in the common life than even the Roman matron won in the days when the Romans were still farmers.

The Anglo-Saxon woman, in particular, arrived at a very happy position, perhaps because the laws of her people were evolved directly from Teutonic custom without any important influence from the canon law or Roman law. The laws of Ine gave a wife a third of her husband's property; and the laws of Edmund allowed this to be increased to one half, if a settlement was made before the marriage. In France vestiges of a primitive mother-right remained, before Charlemagne revised the old Frank common law from a Roman point of view. For instance, if a man died without children, his mother and father equally shared his property; if they were dead, then his maternal aunt inherited before his paternal aunt.

QUEEN ELIZABETH IN A COSTUME OF THE PERIOD

Unfortunately for the Englishwoman, the laws of the Scandinavians were entirely different from the laws of the Teutons in regard to the rights of women. Perhaps the art of agriculture was much less practised in the more northerly and colder country, and the economic value of women diminished. The maids and wives of the Scandinavians were under perpetual guardianship. Up to the end of the seventeenth century, under Christian V., the guardian of a woman obtained the benefit and administration of her goods during her life, if she married without his consent. What that meant in practice can easily be imagined. We know it from our own history, for we have had some experience of the rigour of Scandinavian law. First came the Danes, sweeping Great Britain and Ireland; and then, a few days after the last Norwegian raid, another branch of the Norway clans—the Normans—conquered England and Wales, and invaded Ireland, and made Norman law the law of the land.

Swift and profound was then the degradation of the Anglo-Saxon woman. The person and property of a wife became entirely at her husband's disposal. A woman could not even accuse a man of murder, except only in the case where it was her own husband who had been killed. It was the day of the strong hand and the hard heart, when all things went according to

"The good old rule, the simple plan,
That they should take who had the power
And they should keep who can."

And woman, being unable to keep anything in her gentle hands, lost everything. In the silence of a moonlight night, the harshest and the ugliest scene often puts on a wild, romantic beauty; factory chimneys loom out of the darkness like enchanted minarets, and unlovely stacks of cheap bricks and mortar show dimly forth, like mysterious castles. So, in the silence and moonlight of history, the mean, brutal savage age of feudalism takes on the soft, quiet, glimmering colours of romance.

But, as a matter of fact, most of this romance is false; and where it is not false it is often unseemly. Open rapine and underhanded cunning, barbaric violence, mitigated by fits of superstition, formed the prose reality of the age of chivalry; and nearly

all the poetry of the age celebrated adulterous love. Scarcely a single love lyric of the troubadors and other minstrel knights was addressed to an innocent, unmarried girl. Not until the Freemen of the middle classes in the towns of the Middle Ages became strong and wealthy and independent enough to create a culture of their own, did mediæval literature acquire a purer tone, and women win an honourable position again in society.

It is true that, when strict military service was not required from the feudal landowner, the lot of the noblewoman was somewhat improved. She was then often allowed, in the absence of a male heir, to succeed to a fief. But even the great heiress was not free in the one matter of high concern to her. She often had to marry the man chosen by her overlord; she was a piece of valuable property, a prize of great price in the feudal game of slaughter, intrigue, and treachery; and when Europe became more settled in the fourteenth century, female heirship was largely abolished. For instance, the Golden Bull of 1356 declared that all the fiefs held directly of the Empire would only be transmissible to male heirs.

THE JAPANESE WOMAN IN HER ELEMENT

Though the women of Japan have no public rights, they reign domestically in their homes more completely than any other Asiatic women, and their kitchens, as here shown, are models of cleanliness and culinary efficiency.

"One should not teach any woman to read or write," says a French writer of the twelfth century, "if it is not especially to make her a nun. For it is extremely unbecoming in a woman to read or write."

Woman, however, had one weapon left, and when she belonged to the middle classes of the trading towns she used it. There were things she could make and sell as well as a man could. In many country districts the communal type of family obtained, and there the woman of the peasant class merged her activities in the activities of the group. In cities, however, there was scope for individual enterprise; and here, in the thirteenth century, we find woman entering single-handed into commerce. For women merchants were then given the right to bring actions at law without their husbands' consent—a thing a French woman now cannot do. In England in the fifteenth century there was a successful agitation for the protection of the trade interests of woman. These events, nevertheless, are like many other single instances of feminine rights and powers in the history of mediæval Europe. Collected together, they give an impression of progress, which is not confirmed when the sparsely scattered and almost accidental facts are studied in their natural order of date and place.

Yet the great European nations of the Middle Ages never lost entirely their high, traditional idea of woman. After all, they came from the race which definitely instituted monogamy. In the darkest days of the mediæval era, a Catherine of Siena, a Joan of Arc, showed, by the extraordinary power she exercised over the soldiery and the politicians of Europe, that the majority of the common people still recognised and responded to the feeling embodied in the figures of the Mother and Child which they placed in their churches. This deep and ancient undercurrent of emotion found clearer expression when the middle classes began to win their way to political power. As civilisation and free institutions developed, the woman of the more advanced nations recovered somewhat of the high status possessed by the Roman matron under the later Emperors.

In all kinds of ways she regained her economic value; the first daily English newspaper, for instance, was established by a woman. A considerable part of the textile trade was a domestic industry carried on by

women in their own homes, and the housewife made most of the things which her modern descendants obtained from factories. In Elizabethan England, women, as we know, were allowed considerable personal freedom; and in the troubled period of the seventeenth century they gave many examples of a strength and a resolution of character which can be compared only with the splendid qualities of the Roman woman of antiquity.

At the Restoration, however, the English woman's lot changed for the worst. Her brief period of spiritual emancipation had not lasted long enough for the old harsh feudal laws to be modified in her favour; and the Puritans left behind them, especially in the works of Milton, much of the old Jewish and Oriental view of the subjection of woman. As we shall see in the next chapter, the English woman was saved, partly by the natural progress of civilisation, partly by the efforts of a few clergymen who established a fine system of education for the girls of the middle classes, partly by the invention of the steam-engine, but mainly by her own genius.

At the present day, the woman of the Anglo-Saxon races is starting throughout the world a movement of tremendous importance. She is, more by example than direct teaching, sowing the seeds of revolt over all the earth, and arousing her sisters from their slavery, just as the man of the Anglo-Saxon races is creating in the ancient despotisms of the Orient a series of revolutions in favour of free institutions of Government. If both these movements succeed, then the form of family life in the East will be profoundly modified. The Chinese woman will no longer resemble the Athenian woman of the age of Pericles; the Turkish woman, too, will escape from her harem; and the Japanese woman, who is already changing, will have a soul of her own.

If the full exercise of natural intelligence by the mothers of a race has any effect on their children by reason of the better training they are able to give them, if a marvellous increase in the force of character and play of mind of one half of a nation adds to that nation's moral and intellectual power, then it seems likely that Pericles of Athens, Confucius of China, Manu of India, and the sages of Islam and Israel were gravely at fault in making the practical enslavement of woman the foundation of a civilisation.

Athens perished less than a hundred years after the death of Pericles; India, once the centre of the thought of the world, has lived on, in a sort of senile immortality, thinking over and over the thoughts she struck out in the days when her women had part in her national life; the Jews have shut themselves up in the traditions of the patriarchal age, and compelled their finest spirits, like Spinoza, to leave them in order to speak to civilised humanity; the Chinese mind has stagnated since the days of Confucius; and Islam, once the spear-head of civilisation, has fallen back almost to barbarism. This is perhaps a sufficient answer to the question we started at the beginning of this chapter.

JOHN MILTON, WHO ADVOCATED THE SUBJECTION OF WOMEN, DICTATING TO HIS DAUGHTERS

WOMAN TEMPTED FROM HER TRUE WORK

The women chainmakers of Cradley Heath, working for a wretched pittance at tasks only fit for men are one of the worst examples of our strange disregard of the true mission of England's mothers. The best the chainmakers can do for their little children is to take them with them into the grime of the forge

THE RIGHTS OF MOTHERS

The Supreme Duty of Individuals and the State, and the First Charge Upon a Nation's Resources

LESSONS THE ZULUS CAN TEACH ENGLAND

If we wish to grow oaks, we admit the rights of acorns to due nurture from the first; and as we note that claim we remember that the acorn, even, has its period of formation and development in the maternal tissues of the tree which bore it. If we wish to grow men and women, we similarly admit the claims of their earliest stages to due nurture; and at once we are met, to the dismay of many who will admit the claim on paper, with a simple fact which, hitherto, practically everyone has forgotten. Man is a mammal, which means that a very early stage, usually thought to be the first stage, of his nurture depends upon the maternal bosom: already we may see complications ahead.

But a mammal is not only a creature of which the female suckles her young; it is a creature of which the young are brought forth alive. In the accepted term, mammals are "viviparous," not "oviparous," like the birds and reptiles, which lay eggs. Hence the first stage of nurture is ante-natal; and if we really mean what we say when we demand proper nurture for the next generation, we find that the complication involved in the fact that the next generation should be breast-fed in infancy is nothing to the further complication that the only way in which to achieve its nurture from the beginning is to take care of expectant motherhood. That, perhaps, is rather more than a good many lip-servers of eugenics had bargained for, but they have already committed themselves to it, however unwarily.

The "expectant mother" is a beautiful phrase, invaluable to the Eugenist, who can freely employ it in his public propaganda, not merely without offence, but with the advantage that the phrase exactly expresses what ought to be the mental attitude of every future mother. We err, indeed, to say "future mother," or "about to become a mother," for the expectant mother is already a mother. She and her child already need our care; and we shall only meet the demands of eugenics when we really see the fact as it evidently is. For several years the writer has been asking, by voice and by pen, for a reference to the first user of this beautiful phrase, the "expectant mother," and no one has ever yet answered the question. Judging by the legal phrase "expectant heir," one suspects that the phrase may have a legal origin. Anyhow, it is beautiful and useful: and the request is here repeated for information as to its introduction.

Whenever and wherever eugenics is or has been consciously practised—whether by Lycurgus in Sparta eight centuries before Christ, or by the Jews, or by the finest of modern "savages" so-called, or in the legislation of a few progressive nations to-day—there the needs of expectant motherhood have been recognised. We are all familiar with the fact that the expectant mother who has been condemned to be hanged is reprieved. The fact is simple, and appeals to everyone as sociologically just and right. But to admit so much is to admit everything; it is to grant the whole principle of the rights of the unborn, the rights of the next generation to ante-natal care—care which we can only grant by caring for the expectant mother.

We are agreed that the murderess must be reprieved rather than that we, in punishing her, should murder the unborn. The claim is here made for the first, but certainly not for the last, time that what we grant for the unborn child of the murderess, and therefore for her, we must henceforth grant for all unborn children and for all their mothers. We say that, though the murderess has taken a life, she is now creating a life; and for the sake of that life, not for her

sake, we spare her, and admit what is practically a legal right to exemption from legal punishment and to special care, on behalf of the life which she is creating. Here we demand as good treatment for all mothers as for those who are murderesses as well.

This tremendous illustration—which the writer, having argued the claims of motherhood for many years, is ashamed never to have seen until now—also serves the purpose of showing clearly what is meant when we formulate, as here we do, the essential principle of the Rights of Mothers.

The Most Natural of All Rights—the Rights of Mothers

For the cautious and thoughtful may well be alarmed when first they hear the phrase for which we here seek their acceptance. Such people are all very well aware that we hear far too much of rights to-day and far too little of duties. The past, indeed, was just as bad: and no writer could venture to make such a claim as we make here, for the universal recognition of a new-old principle, unless he could be sure that its basis was a very different one from that of " the divine right of kings," " the rights of wives," the "rights of minorities," " the right to live," " the right to work," " the rights of women," or some of the almost incredible and nameless rights which were claimed by, say, the lords of the manor over helpless bridehood not very many years ago.

The only " divine right of kings " is, as Carlyle said, the divine right to be kingly men ; as for the " right to work," meaning the right to wages, asserted too often by those who have no idea of what work is, that and many other claims, however intelligible or even just, have no ultimate foundation in Nature such as is here claimed unhesitatingly for the Rights of Mothers.

Where We May Safely Take Lessons from so-called Savages

It is to be doubted whether anyone else can claim, for him or her self, any real and final right that can for a moment compare with the right of a mother to fair conditions in which to perform her supreme and indispensable work. That is a right worth having and worth claiming by all who know a fundamental principle when they see one. As to other rights, people may argue *pro* and *con*, but in asserting the Rights of Mothers we are beyond challenge, so long as individuals are mortal, and parenthood alone can replenish the race. The basis of this claim is not political, but biological; it is not peculiar to civilisation, nor even to man, but depends upon the method of Life's advance, by birth and death. What is said here is based upon " the solid ground of Nature," whereto, as Wordsworth said, " trusts the mind which builds for aye." The Rights of Mothers, vitally speaking, are the rights of the future, which mothers produce. No living race, of plants or animals or men, survives which does not sufficiently recognise the claims of the future upon the present; and for us these claims take the form of the natural rights of mothers, recognised at this hour by many primitive peoples, such as the Zulus and the Maoris, whom we, with our infant mortality, our mothers in the mills, our countless deserted mothers, our broken army of widows and orphans, have the effrontery to call savages.

Observe that we are not here asserting the rights of women, as such, or the rights of wives, as such, any more than public opinion and practice assert the rights of murderesses in the case we have cited. That is why this last illustration is so cogent. It clearly proves, by an appeal to present admitted practice, which no one would dare to question, that the mother, as a mother, has a right—not hers in reality, but her child's, or hers for her child ; a right such that the rights of justice must be set aside lest a deeper injustice be committed upon the young life yet unborn.

The Safeguarding of Mothers Means the Guardianship of the Future

It must be clear, then, that we are not claiming anything for wives, or anything for women, but only for mothers as mothers: and our claim, so far, is evidently none other than the claim, already granted in principle, that the next generation is entitled to due nurture.

Once more let us employ the illustration of the reprieved murderess. We grant that the mother's crime does not permit us to commit a similar crime upon her innocent child. Then certainly we must admit as much for the unmarried mother and her child—unless to be an unmarried mother is so much worse a crime than murder that it justifies us in an act of vengeance not only upon the criminal but also upon her unknowing baby. To this there is no reply, and we are not even called upon to pretend that it is even arguable and is submitted to public opinion for decision. If public opinion questions it, so much the worse for public opinion. No one really questions it, no one dare ; but where in our civilisation can we point to the just care of the unmarried mother, and what are the appalling figures of comparative infant mortality which every year brings forth?

Everyone knows, or should know, that, notwithstanding what public opinion and the law declare or pretend, illegitimate motherhood is cruelly treated among us, and illegitimate babies die in horrible numbers because the everlasting principle of the Rights of Mothers is not granted among us.

Lest any reader should, most reasonably, point to the social danger which might threaten if we examined our principle no farther, let us note that we shall shortly consider the exact place and responsibility of fathers, married or unmarried, in granting mothers' rights. Meanwhile we may prepare ourselves to consider what all this involves for fatherhood by the salutary recollection of the "savage" practice of the Zulus in such cases.

The tribe is summoned in conclave, the unmarried mother's plight is stated, the unmarried men are asked to offer themselves, if they will, to marry and protect her; and when one of them has been chosen, and she and the future of the race have been thus provided for, the young warriors dispatch the father with their assegais. Savage, no doubt, in practice, but sound in principle.

A Comparison Between England and Zululand which Sets Us Tainking

And how immeasurably less savage than our practice, which is to let the father go scot-free, and to persecute the mother, so that either her child dies, or, as too often happens, she kills it in her melancholia, whereupon we sentence her to be hanged, though without intention of carrying the sentence out, thus proclaiming ourselves ridiculous as well as brutal! Let anyone seriously compare Zululand and England in respect of these contrasted methods of dealing with illegitimacy, and content himself with the usual meanings of "savage" and "civilised," if he can.

It is impossible to think usefully of the Rights of Mothers without realising that this is, from first to last, a question involving fathers too. Wherever we turn for lessons and instruction from the world of life, we find that this is so. The beehive is a notable illustration. Here is a great community which is based wholly upon the principle of the rights of the one mother upon whom the future depends. Men used to think that the mother was the "queen," and gave orders and ruled the hive. This they inferred from the fact that the hive evidently exists for her, and that no one lives or moves therein but in her service.

The "queen bee" gives no orders, and does not even direct or control a single stage of her own conduct or nurture. She is not the "queen bee," and should not be so called, unless we mean thereby to declare that the mother-bee (the name by which she should be called) is the "queen of the hive," because she is the one mother in it. The whole future of the stock absolutely depends upon that one mother, and her rights are granted. If the whole of our next generation were to be born of one mother, we should take care of her too.

Lessons in Parenthood from the Hive and the Streamlet

As for the drones, they are kept for fatherhood, and for nothing else. So soon as the queen is fertilised by one of them, they, being thereafter useless, are one and all destroyed. The theory of the bee is the theory of life—that *the useless have no rights.* So the one mother is served with the rights of a queen, served as no human queen was ever served, and the useless males, which would otherwise consume the food which is destined for her children, are promptly killed. We are more lenient with our human drones—fathers whose fatherhood extends no farther than their pleasure and we often allow them to consume their children's bread, but we shall be as wise as the bees some day.

Remembering the principle here enunciated, that the useless have no rights, let us contrast with the drone another type of father. There is the little stickleback father, who builds a sort of nest for his mate and their children, and then does a sort of sentry-go beside it, to keep off intruders. He knows and grants the rights of mothers, and does not die after fertilisation of the ova, for his work is not then done, but only just begun.

If we are to learn the ancient lesson of Life, it is evident that we must take care of all babies and all mothers, young or old, high or low, married or unmarried.

The Mother as the True Beginning for All Real Progress in Health

We regret the unmarriage of many a mother; we should have taken better care of her adolescence and her betrayer's. Our business now is to take care of her, and of the new life for which we are doubly responsible. The rights of mothers, then, are neither legal nor "moral"—in the customary sense of *customary*—they are vital and natural, moral in the ultimate and eternal sense.

If we are to have fine people we must begin at the beginning, which is not the rifle-bearing age, nor childhood, nor

infancy, but earlier still. And even though the motherhood we care for may often be worthless, we must care for it none the less, not least in order that the feeble-minded girl, for instance, may be so protected that she can never become a mother again.

It must be remembered that, though our present subject is termed the Rights of Mothers, we are really beginning at the beginning of Nurtural Eugenics, and that it is this beginning which has forced the expectant mother upon our attention, since she is the first nurture and first environment of the next generation. But it is noteworthy that this logical order, which puts expectant motherhood in the first place, has not been followed by social reformers. On the contrary, philanthropists, educationists, and politicians have begun anywhere but with the mother; and it is only the logic of facts and events that is now slowly forcing their attention back to the point where the logic of science and causation should long ago have directed them to begin.

The recent history of thought and practice is clear and instructive. We began by deploring the condition of young male adults, during and after the Boer War, from the point of view of the recruiting-sergeant.

The Roundabout Discovery of the Neglected Child, through the Rickety Recruit

The proposed national remedy—not, of course, proposed by anyone who had ever studied physiology or the laws of health—was physical training of such young adults, thus ignoring the whole of one sex, and assuming that exercises or dumb-bells can straighten knock-knees produced by rickets fifteen years previously, or replace teeth whose sockets have been empty for a decade.

Such puerilities could not impose upon an unprejudiced baby, and observers and propagandists were compelled to go back a little. They did so, and not unnaturally discovered the school-child, an amazing if somewhat obvious revelation. The school-children were found to be in a deplorable state, and we agreed that we must regularly inspect them. As we do not treat them, no one has been able hitherto to guess why we should go to the trouble and expense of inspecting them, but the process sounds military and efficient; and there are optimists who dream of a day when the hideous brutality and folly of recognising and enumerating grave remediable disease in the nation's children without making any adequate attempt to treat it may join the other enormities of the past.

But at least the child and its condition was discovered. Yet nothing could foil the unweary genius of these investigators, once it got afoot. With searching logic, having inferred, from the adolescent, the possible existence of childhood, they inferred from childhood the probability of babyhood; and after critical and patient inquiry their ratiocination was justified. There *were* babies. Furthermore, these babies died by scores of thousands yearly, and a far larger number, who did not die, were damaged, and that for life.

The State of Babyhood that Determines the State of Armies and Nations

The campaign which had begun with proposals for drilling recruits in barrack-yards was compelled to condescend upon the care of infancy, it having been proved up to the hilt that you cannot have a soldier or a sailor, or even a simple citizen, without having first saved a baby. It seems an unnecessary indignity, imposed by Nature upon the martial spirit, to indicate its dependence upon such effeminate considerations, but there seems no choice for our champions but to swallow the affront as best they may. At least they may remember the estimation in which Napoleon held motherhood, and claim the introduction of "maternity benefits" as a great practical service to those who put their trust in legions, as it certainly will prove to be.

But the logic of facts has forced us back further still. Here in this country we are following the French, whose military exigencies and falling birth-rate, together with the humanitarian genius of the late Professor Budin of Paris, have caused them to lead the way in this matter.

The Point that Science has Reached in the Great Campaign of Civilisation

Budin provided sterilised milk, with much success. But soon he and his followers did better. They fed the nursing mother, which is much cheaper, much safer, much better for the baby, and not exactly injurious to the mother. And once again they had to go back a little. They started feeding the expectant mother; and that is the point which practice and science have now finally reached in the great campaign of civilisation against infant mortality and for the right nurture of the next generation.

This brief history is what has actually happened in thought and practice in the course of just ten years—and it will be seen that in that period we have travelled, led by the necessities of Nature's laws, step by step steadily backwards in our care, from the adult to adolescence, adolescence to

childhood, childhood to infancy, and infancy to expectant motherhood—to the point, that is to say, which any student of the laws of life would have indicated as the necessary beginning.

At the present hour this is the youngest, the most promising, and even the most topical of questions. Science, practice, and now even legislation have converged upon the problem of expectant motherhood, once and for all. They have been a long time in getting there, but there they will stay while and if civilisation endures. Our national task is now to accept the permanent principle, here laid down—that *its expectant motherhood should and must be the first charge upon the resources of any nation*, and to solve the economic and social problems which this proposition involves. They are economic, because they concern the whole question of "married women's labour," and social, because they involve the whole question of marriage and the duties of fatherhood.

But the Eugenist is false and faithless if he shrinks from enunciating his demand for expectant motherhood merely because there are difficulties in the way; as he is foolish if he does not recognise them and ask for the sympathy and co-operation of all parties and classes in the attempt to meet the tremendous need which the ever-falling birth-rate yearly makes more urgent.

Pioneers in the Most Fruitful of All Health Studies

It is only within the last fifteen years, beginning with the epoch-making work of the Frenchman Pinard, that science has really come to its own in the study of expectant motherhood. He and a few others, notably Dr. J. W. Ballantyne of Edinburgh, persistently devoted themselves to the study of ante-natal health and disease, ignoring the charges of wasting their time which others brought against them, as against the young Pasteur.

The present writer remembers, as a boy, a conversation with Dr. Ballantyne, in which the devoted student, alluding to the completion of his great book, now classic, on "Ante-Natal Pathology," used some such words as these: "They laugh at me, as they laughed at Pasteur, but we shall see." The boy then thought that such studies were more curious than useful; he now declares his conviction that they are vital and fundamental to the greatest ideal ever set before mankind.

These great pioneers have proved that the state and prospects of the infant at birth are greatly affected by the conditions that precede the birth; and these conditions, alas! are often anything but what they should be. The babies born of working women who can rest—as we stupidly call it, for how can an expectant mother "rest"? —during the later months of expectant motherhood are markedly larger and finer than those of mothers who have had to work in the obvious way to nearly the end.

The Most Recent and Complete Summary of Real Knowledge of the Subject

We may quote the most recent summary of the evidence on this point: "Such rest is a powerful agent in preventing premature birth. This is an important matter, for in civilised countries to-day—notably in England and France—it is estimated that about one-third of the births are premature; and the child who is born before its time comes into the world in a relatively unprotected state, and is unduly liable to perish, or else to lead a permanently enfeebled life. In most English towns immaturity is regarded as the chief single cause of infant mortality, accounting for about 30 per cent. of infant deaths, and for a large proportion of relatively defective individuals among the survivors.

"It has been found that rest during the later months of pregnancy is a powerful influence in the prevention of the birth of immature children; the average period of development within its mother's body is three weeks longer for the child of the mother who rests during the latter months of pregnancy—for rest during the earlier months has comparatively little influence on the child—as compared with the child of the mother who has enjoyed no such rest.

"Such opportunity for completing its development is of immense and lifelong advantage to the new-born infant, while the rest is also of benefit to the mother, who cannot with impunity stand the double strain of work and of nourishing the future child within her. Yet the importance of such rest for women, in its bearing on the elevation of the race and the lightening of social burdens, is still understood by few, and is not adequately insisted on and provided for by the laws of any nation.

The Time when Every Working Woman Should Have Rest

"More than ten years ago (in 1900), the International Congress on Hygiene passed a resolution that 'every working woman is entitled to rest during the last three months of her pregnancy.' No such measure can be anywhere realised without the active co-operation of the community, providing

for the mother during the period of enforced rest, but no community has yet shown itself intelligent enough to realise the need of making such provision in its own interest.

"So true is it, as a distinguished authority has stated, that 'to-day, the dregs of the human species—the blind, the deaf-mute, the degenerate, the nervous, the vicious, the idiotic, the imbecile, the cretin, the epileptic—are better protected than pregnant women.' We shall some day have to reverse this estimate of the values of things."

The Lamentable Teaching which Believes in "Better Dead"

So writes Dr. Havelock Ellis, whose illustrious authority may be cited against the lamentable teaching of Professor Karl Pearson, who has just issued a lecture in which he deprecates our attempts to protect expectant motherhood, on the "better dead" theory of infant mortality.

The reader who desires to go more closely into the evidence for the view here taken, and supported by the evidence of all first-hand workers at the problem, should consult the standard treatise on "Infantile Mortality," lately written by Sir George Newman at the present writer's request. In this book, for the first time, the evidence regarding prematurity as a cause of infant mortality and infant injury is duly stated and appraised; and, if any more be needed, we may consult the paper on the ante-natal factors of infant mortality contributed by Dr. Ballantyne to the first National Conference on the subject, recently held in Westminster. But the quotation from Dr. Havelock Ellis may suffice as the most recent and complete summary of real knowledge of the subject.

The Culture of the Racial Life is the Vital Industry of any People

The ultimate principle, biological, sociological, and eugenic, which we are here advocating under the name of the Rights of Mothers, is abundantly supported by these considerations. We see, now, that the expectant mother is in actual fact working, and that if we ask her to do any other kind of work we are simply sacrificing the future to the present; but Nature never fails to avenge herself on the spendthrift, individual or nation. Our business is to recognise that the expectant mother is doing our business, indispensable and exacting business, and we must take care of her accordingly. She is a worker, and the foremost of all workers.

Of course, what we here argue applies to the nursing mother, and to the second stage of nurture, which is the nursling stage, just as much, or almost as much, as it applies to the expectant mother. The nursing mother is also in fact a worker, and an indispensable one, Budin's work with sterilised milk notwithstanding.

To consider the chemical energy expended in the production of milk alone, it has been estimated that the production of milk for six months' nursing involves the same amount of work as would raise a ton-weight eight hundred feet high. When we consider what this work is for, what it is that the expectant and nursing mother produces, and what kinds of thing are produced by most of our national industries, there is surely warrant for declaring, yet again, that the culture of the racial life is the vital industry of any people; that the economic rights of mothers, as mothers, are therefore paramount; and that she who creates the future, the maker of life and carer for life, is surely the last person to be in a position of economic insecurity in a sanely constructed society.

The Only Natural and Indefeasible Rights are the Rights of the Useful

The useless have no rights; the only natural and indefeasible rights are the rights of the useful, and of these the mothers are first—not in a moral or sentimental sense, but in a logical and practical sense. In the State of the future, if anyone is secure, if anyone is on a natural throne—like the queen or mother bee—it will be she who makes and nourishes the life of this world to come.

There remains the problem of ways and means—which we must keep clear and definite in our minds, and consider apart from the merits of our principle. If we confuse the principle with the economics of its application, we prejudice both. No difficulties or controversies between proposed solutions of them are to prejudice the principle. No one has written more profoundly than Ruskin upon economics; they laughed when he wrote, but now we read and learn.

Ruskin knew that the principles of life must come first, and the methods of economics second. "I hold," he said, "that the two crowning and most accursed sins of society of this present day are the carelessness with which it regards the betrayal of women, and the brutality with which it suffers the neglect of children." And again said Ruskin: "Finally, I hold it for indisputable that the first duty of the State is to see that every child born therein shall be

well housed, clothed, fed, and educated, till it attain years of discretion."

Here some champions of what they call progress intervene with a simple suggestion, designed to meet the case, but somewhat more designing than this case requires, which they call the Endowment of Motherhood. Between their proposals and those here made, there is an everlasting opposition which no similarity of terms or even ostensible objects can cloak. The so-called Endowment of Motherhood (by the State) proposes to serve Motherhood by discharging Fatherhood from its duties. On whatever road the feet of Progress and Eugenics may fare, this is none of them. It is not progress, but full retreat, helter-skelter back to the beast.

The popular novelist whose name is chiefly associated with such proposals in this country, declaring that the business of the State is now to abolish the private family as it has abolished the private gasworks, and dismissing, as, "a matter of detail," the question whether the father should have any share in the upbringing of his children, is directly contravening the age-long principle that men must be more, and not less, responsible for their acts, and, above all, the principle now demanded by eugenics, that men must be most of all responsible for the most momentous and deliberate act of all, which is fatherhood.

The fundamental institution of marriage expresses, and has always expressed, the idea, which eugenics means, if it means anything, that parenthood is to become more, and not less, responsible. Modern thinkers clearly see this as regards the mother; those writers who do not see it as regards the father can scarcely claim the higher title. The essence of marriage as a social institution—it is also a personal institution, of course—is that it provides common parental care of the offspring, and exacts a common responsibility.

If we are asked where this doctrine of the Rights of Mothers is really acknowledged by mankind, we need only point to the universal institution of marriage, which exacts from the father certain duties towards the mother and her child. The duty

THE WORK THAT DRAWS THE MOTHER FROM THE HOME

of the State, and the business of Religion, in all ages, has been, not to do the father's duty for him, but to enable, and to compel, him to do his. If the father be dead, or if he be ill, and thus unable to do his duty, the business of the truly united Church and State, and the business of every Eugenist, will be to obey the words of St. James: "Pure religion and undefiled before God and the Father is this, to visit the fatherless and widows in their affliction, and to keep himself unspotted from the world."

The Business of Social Institutions—To Help Fatherhood to Fulfil Its Duties

Such, then, is the next step in the argument which has proceeded from our recognition of nurture at all. We have been forced back and back to beginnings; and now we reach the father of the new child, and assert that the principle of the Rights of Mothers—that is to say, the rights of children and the future—involves Duties of Fathers; that the business of social institutions, from marriage itself up to the Church and State, is to enable the father to do his duty, and to take his place when he cannot. If the father will not do his duty naturally to the child, then he must be compelled to do it by the State.

The legislative possibilities are numberless. Their variety and scope may fitly be illustrated if, first mentioning the law of marriage, so old that mankind itself is young by comparison, we conclude by referring to the system of national maternity benefits introduced by the National Insurance Act. The most immediate eugenic need, so far as nurture is concerned, is the right care of all expectant motherhood, primarily dependent upon compelling and enabling all fathers, married or unmarried, properly to discharge their paternal duties.

The Magnificent Recognition of Motherhood in the National Insurance Act

The duty of the State is to help the father to do his; and the plan of the Insurance Act, whereby the prospective father will be compelled, in millions of cases, at any rate, to put money aside so as to contribute towards the care of his wife when she becomes a mother, is thus absolutely and ultimately sound. No true Eugenist can hesitate for a moment to applaud it with all his might. The maternity benefit—which the Act so rightly guards against becoming a publicans' benefit—comes out of the men's pockets, and is definitely directed to the service of expectant motherhood and childbirth.

The present benefit is a mere beginning, but it is the beginning of magnificent things. Two weeks' "rest" before and after childbirth is so far from the demands of Nature as to be almost farcical, but its superiority to present conditions is tragic. We have seen what the International Congress of Hygiene laid down a decade ago; and we need scarcely remind ourselves how totally inadequate so little "rest" is to prevent hundreds of thousands of premature births from occurring every year. Nevertheless, this legislative provision evidently marks an epoch in the real history of civilisation. No other modern country has yet done anything to approach it; and we may well hope that, in perhaps another century, the laws of England may guard the rights of mothers nearly as well as the laws of Moses have done these past three thousand years.

Above all, the new legislation will begin to provide for the nation's mothers the fundamental need of safe and skilful attendance when it is most needed. The work of Pasteur and Lister has made a new age in this respect, yet several thousands of mothers die in consequence of childbirth in this country every year for lack of responsible care; and not one of those who thunder about the falling birth-rate has one word to say about the unnecessary destruction of those who make all the birth-rate there is.

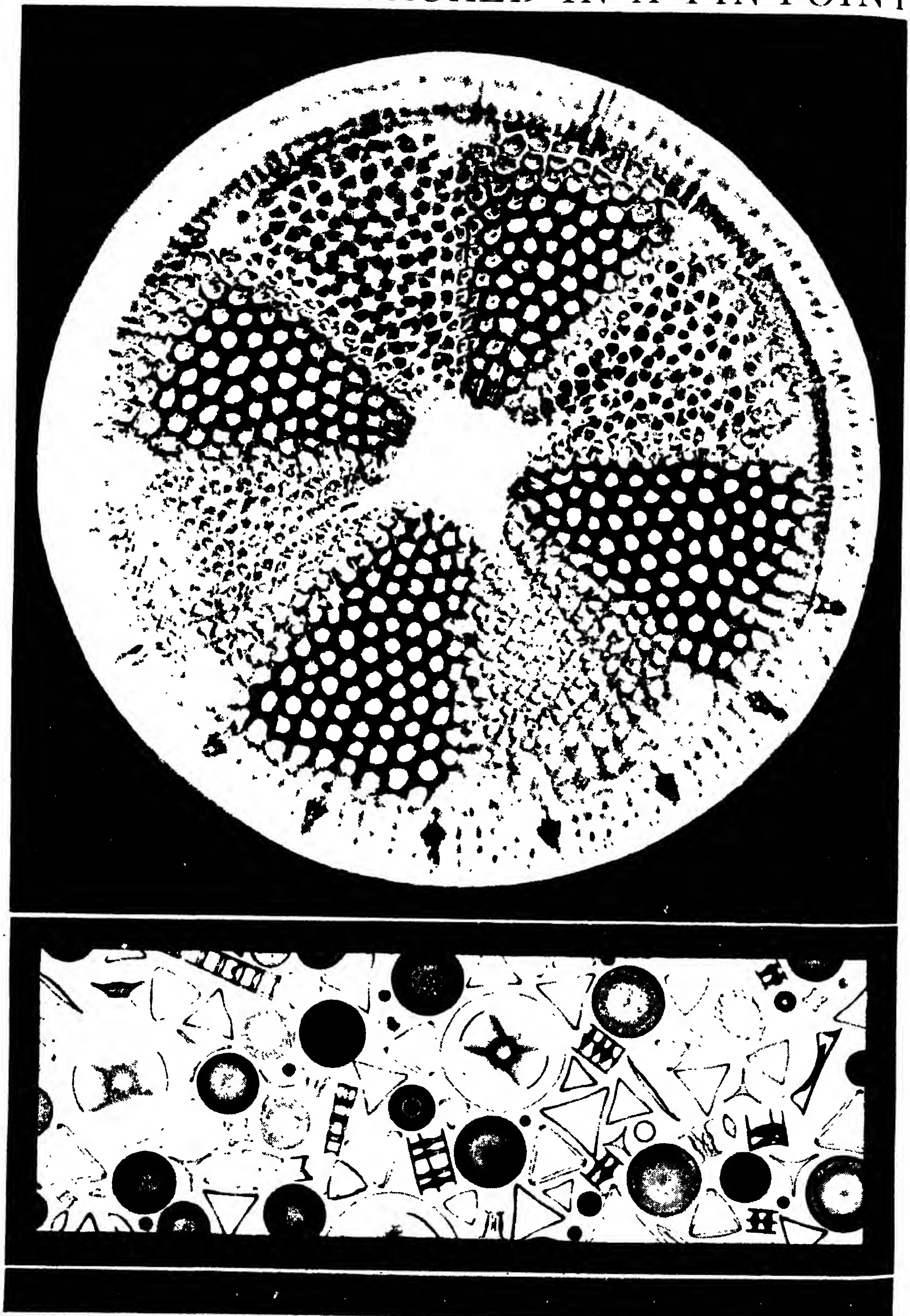
Why not Apply to the Creation of Life as Much Knowledge as is Lavished on Engines of Death?

The writer here repeats his demand, which will certainly one day be granted, for the establishment, in association with the system of maternity benefits, of a class of State Obstetricians, keen, clean, competent men and women, Listerian to their finger-tips, who shall protect and serve the nation's mothers, and keep them alive and well for future motherhood. This will enormously reduce infant mortality; it will save thousands of mothers from dying of gross carelessness and negligence; and it will leave half our special hospitals for women untenanted, since the crisis of motherhood will no longer damage thousands of women for life.

Surely the first of the Rights of Mothers to-day is that, in this age of Listerism and bacteriological knowledge, they shall no longer be poisoned and killed, or damaged for life, by our failure to apply to this supreme case, the creation of life, the knowledge which we already apply upon the battle-field to the arts of its destruction.

In such ways as these it shall be that England, "as a Christian mother, may at last attain to the virtues and the treasures of a Heathen one, and be able to lead forth her Sons, saying, 'These are MY Jewels.'"

THE WONDER PACKED IN A PIN-POINT



THE MARVELLOUS BEAUTY THAT LIES IN THE WATER-PLANT KNOWN AS A DIATOM

The diatom is suggested in its natural size by the pin-points at the bottom ; above is a group photographed under the microscope ; and at the top is a single diatom magnified to a million times its proper size, revealing the almost incredible wonder that Nature can pack into a speck often invisible to the eye.

THE MAGIC OF MOTION

Some of the Stupendous Facts that Newton and Galileo Found and Missed While Studying

THE EVERLASTING LAWS OF EVERYWHERE

THE law of gravitation is truly universal, we have seen, and stands as a great instance of such laws, but it is not alone. On the contrary, as we have seen, it expresses the action of one of many forces, one of many laws, which determine the course of things; and though it appears to be one of the "prime movers" of bodies, heavenly and earthly, it is certainly only one of them. If it were the only one, all the matter in the universe would lie in one dense heap, and there would be no science of astronomy. We saw that in the movements of the solar system gravitation counteracts or balances, or is balanced by, other forces and other laws, and that the course and order of the planets and their satellites is the result not of any one of these, but of all. It follows that we have much to learn yet before we are entitled to take up the study of any particular part of the heavens—that is, if we wish not merely to be interested or pleased, but also to understand.

All things move, stars compared with which the sun is a spark, or the ultimate specks of which this paper is composed. Living things move, as all others do. We can express our will and character only by moving things—portions of ourselves, or things outside us. We may demur to these assertions, and quote instances of rest. But not until we thoroughly understand that there is no such thing as rest, and that what we call rest is really something else, shall we be able to study universal motion, or to place ourselves abreast of the profoundest thinkers of our modern age, from Henri Bergson downwards.

It is plain, in the first place, that when we speak of motion we are always thinking of something that is relative. Certainly there might be one point of substance, alone in infinite space, and that point might move. Whatever motion it made would be absolute, not apparent, not relative to anything. We must certainly believe in real, absolute motion. But in this imaginary case, if we could observe it from nowhere, the absolute motion of this particle would be beyond our detection. Not being relative to anything, it would not be apparent; but, of course, if we were "there," or anywhere, we could observe the point's motion at once, for then we should have ourselves and our position to measure it by—it would move to us, or from us, or past us. Thus we establish two great ultimate propositions: there is absolute motion, but all the motion we know or can know is relative.

And evidently what is true of motion is true of rest. We are entitled to imagine absolute rest if we are entitled to imagine absolute motion. Our solitary speck in space may move, or it may not move. But all the rest we know or can know is relative; and when we look more closely into any supposed case of rest, we see that it is never more than relative, since, as we began by saying, all things move. Further, we can see that the case of the planet, which moves in an ellipse, age after age, under the action of at least two different forces, illustrates what is true not only of planets, or of any moving body, but also of any body that is at what we call rest; all motion and all rest, known to or knowable by us, are *alike* the result of the balance and interaction of forces. If two equal and opposite forces, and none other, are at work, then we shall have a case of rest, which would be *real* rest, in such circumstances—which we do not find in the universe. But if either exceeds the other, there will be corresponding motion. Hence, plainly, there is no difference between rest and motion in the last analysis, one or the other happening according to the particular balance of forces acting at the time.

That motion is the dominant fact of

things we see at once when we look into any supposed case of rest. Not one that we can imagine will stand the test of inquiry; there is always some other force at work, producing a motion which we had forgotten, and which is none the less real though we cannot see it. This page may appear to be at rest, but consider any portion of it, and we find it is not so. It "rests," perhaps, upon a table. The gravitation between it and the earth makes a downward stress, which we call its weight; this the table resists, and so the book rests. Yet, in the first place, all its parts are in motion.

Motion the Dominant Fact Alike in Worlds and in Atoms

The book has a temperature, for, however cold the day, it is certainly nowhere near the nadir of cold at which no heat exists. The heat of the book involves a certain special movement of all its parts. Again, the paper consists of atoms, and each of these, we now know, is a kind of solar system in miniature, with multitudes of lesser particles within it, which appear to be moving at a vastly greater speed than Mercury or Venus. Where is our theory of the page's rest now?

But that is only the beginning, and it might be argued that it is not a fair beginning, for we began by talking of the page as a whole, and we have produced no evidence against the view that that is at rest. Yet we are under a huge delusion, due to the almost irresistible tendency to judge everything by ourselves. Relatively to us, the book is at rest, but neither book, nor we, nor walls, nor floor is at rest. For instance, the earth appears to be steadily, however slowly, shrinking—partly, perhaps, in virtue of its own gravitation, as we presume the sun's substance to be shrinking, and partly in consequence of its slow loss of heat. There may nowadays, in consequence of the discovery of the powers of radium, be some doubt as to this last clause, but the argument can easily spare it.

The Enormous Complexity of the Combined Motions of Things

Thus it seems that book and house and foundations and earth's crust are sinking as a whole; and, on the other hand, the students of the earth will assure us that its crust rises and falls owing to local causes, so that there may be forces now at work which are raising our house and book, and they would need to be measured, if it were possible, against the more general causes of subsidence due to earth-changes as a whole.

Whatever is happening in that respect, we know, incredible though it may appear, that our house and book and selves are in motion, because the surface of the earth is in ceaseless motion; and if we happen to be on the Equator we are travelling some twenty-five thousand miles every twenty-four hours unceasingly. Further, the entire earth, as it spins, also flies round the sun, somewhat faster when nearer to him, somewhat slower when farther from him, as Kepler taught us, but always with a speed of many miles in every second. Lastly, or, rather, lastly so far as we know, the sun himself is in motion, we and our book with him, also with a speed of many miles a second. So much for what we thought to be rest. Even so, no one can say anything of the absolute motion of the sun, and therefore of ourselves. We can only observe the stars, and compare their apparent motions, and say that, relatively to certain stars or groups of stars, the sun appears to move in such and such fashion.

But what the stars in question are really doing themselves we cannot say; and thus we find ourselves in the position of those who daily see the sun rise in the east and set in the west, and infer therefrom that he revolves round the earth. They can only judge of apparent motion, and their verdict is just the reverse of the truth, because that which they assumed—namely, the motionlessness of themselves—is the reverse of the truth.

The Tremendous Problems the Astronomers Have Not Yet Begun to Answer

We do poor credit to the facts of astronomy, or to the skill and courage which astronomers bring to their tremendous problems, if we fail to realise how tremendous they are. People expect astronomers to tell them where and how and why the sun moves, whether he is moving in a straight line or in a curve, whether or not that curve is closed, so that, like ourselves round him, he is describing an orbit round something else. They would expect less if only they realised that our study of motion can only be relative; and they would respect more what the astronomers can give them. No one can say what the Milky Way or Galaxy is doing as a whole, or whether it is doing anything as a whole. Its constituent stars are certainly in motion, in various directions, as the planets of the solar system are in motion, in various directions which are yet orderly. It may be that the Milky Way is a whole, as the solar system is a whole or as an atom is a whole. The Milky Way may be in rotation, for all we know, though in what direction, at what speed, and moved by what forces we know not.

So far already have we travelled from our forefathers' most reasonable supposition of what they called the "fixed stars"; and that is not all. It is one of the theories of many modern astronomers that our stellar universe, as we call it, is only part of the whole universe, just as the solar system, say, is only part of it. There may be real outward limits to the distribution of the stars we know, so that they constitute a system; or possibly the stars we know belong to two such systems, moving past and through each other in opposite directions. We are thus entitled to form the idea that the whole known "universe"—but the term will now require reconsideration—is in motion, and that motion may be of any kind, for all we know: motion in a straight line, motion of vibration, like that of a pendulum, or motion in an orbit. More precisely, it may be the case that the overwhelming majority of all the heavenly objects we know belong to such a system, moving as a whole, or to two such systems. On the other hand, certain objects, such as the great nebula in Andromeda, we now suspect, may belong to a different starry system altogether, or may constitute such a system.

The History of the Immeasurably Gigantic Movements of the Heavens

The modern study of their distance affords results so inconceivably stupendous that the real dimensions of such a body must vastly transcend anything the mere photography or contemplation of them could suggest; and they may be what we are almost tempted to call "universes" in themselves, and in motion, like all things else. What we have hitherto called the starry universe may be only one starry system, or the temporary confluence of two, the like of which may exist in any numbers in infinite space. Any or all of these stellar systems may be in any kind of motion as a whole, quite apart from the number and variety of the motions of suns and solar systems and atoms and electrons within it.

Now, all motion is a mode or form of energy, and displays and obeys the laws of energy in general. The mere magnitude or distance or speed or duration of any motion is of no significance whatever; the laws which govern and are illustrated in the movements of a star, a comet, a "falling star," a cricket-ball, or an electron are absolutely identical. This, also, is one of the ultimate facts of the universe; and has the practical consequence that our study of moving bodies upon the earth may guide us to comprehend and predict the otherwise immeasurably gigantic movements of the heavens.

We know enough already to realise that the laws of motion must certainly "square" with what we have already learnt of the laws of energy, motion being a form of energy. That is indeed so, and prepares us to appreciate the remarkable historical fact that Newton, who discovered and formulated the laws of motion, somehow missed the doctrine of energy and its conservation, though students of his writings declare that he seems practically, or subconsciously, to have realised it, and though it can readily be deduced (now we know!) fr m his own laws.

The Three Great Laws that Underlie All Motion and Cannot Be Ignored

Newton's three laws of motion, not to be confounded with Kepler's three laws of planetary motion, are as follows:

1. Every body remains in a state of rest, or of uniform motion in a straight line, unless it is compelled by impressed forces to change that state.

2. Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which the force acts.

3. Action and reaction are equal and opposite; or the mutual actions between any two bodies are always equal in magnitude, but oppositely directed.

These three brief statements have the most gigantic meanings and consequences. They are always and everywhere true, and they underlie, at every point, the processes by which modern physicists and astronomers pursue their arguments and inquiries to successful conclusions. That is not so with the arguments and inquiries of too many persons, who seek to make machines which ignore Newton's laws; but these people do not come to successful conclusions, and never will, however patient and ingenious and devoted they be.

The Law of Rest or Inertia that is Really a Law of Motion

The first law is the law of inertia, which illustrates and justifies much that we have already said. Observe, first, that the law applies equally to rest or to motion—as was to be expected if we were right in saying that the difference between rest and motion is only apparent, not real, and that rest is, so to say, only a special case of motion. What the law asserts for and of the one it asserts for and of the other. Commonly we accept it and admit it only

as regards rest. It seems reasonable to us that a body at what we call rest should remain in that state until something moves it. That is because our minds, when reasonable, cannot believe in the making of energy (such as motion) out of nothing. But many of those who accept this part of Newton's first law, and thus of the law of the conservation of energy, do not accept its second part, which also corresponds to the second part of the law of the conservation of energy. They are so accustomed to the arrest of moving bodies that they think it more or less natural or spontaneous.

It is not so: no moving body will do anything but continue in motion in a straight line at unchanged speed for ever, unless something stops it. That something may be only the resistance of the air, which we do not see, but it is real nevertheless. The law of inertia is equally and indifferently true of rest and of motion.

One most remarkable and novel observation has been made in very recent years, for the understanding of which we must remind ourselves of Newton's third law—that action and reaction are equal and opposite.

A Repelling Power in the Universe that Sir Isaac Newton Never Knew

We are not to suppose that this case invalidates either law, but it provides a case, probably unique, and possibly of great cosmic importance, where the third law qualifies, but does not "defy," the first.

The case is that of radiation-pressure. We know that every radiating body exerts a pressure or repulsive force, in all directions. This will apply to every body that is hotter than its surroundings, and thus radiates either visible light or invisible but radiant heat. It may apply also to other forms of radiation than these, but they will suffice. So long as the body is at rest, no problem arises. But now let us suppose that it be moving. It still radiates, and exerts an outward pressure in all directions, but no longer equally so. In the direction of its motion, whether that be slow or fast, the body crowds upon or presses after the radiations which it is producing. In that direction, therefore, they will be more frequent and intense. Its radiation-pressure will be greater in the direction of its motion, and the excess will be in proportion to its speed. This excess, in the direction in question, will be all the greater, as compared with the opposite direction, because the radiations are necessarily fewer and less intense in the direction which the body is leaving, for the corresponding reason. We here meet, for the first time, a simple principle which is of wide application. It explains why the pitch of the note produced by, say, a locomotive engine, rises as it approaches, and falls as it leaves us—the higher note being due to the increased number of vibrations which the approaching engine crowds upon us, and the lower note to the converse reason.

Some Wonderful Effects Explained by the Action of Radiation-Pressure

It affords, also, a possibility of measuring the motion of stars in the line of our vision—stars moving directly to or from us—for the radiations of light will be more intense in the former case and less so in the latter, and the consequent change in the quality of the light can be estimated.

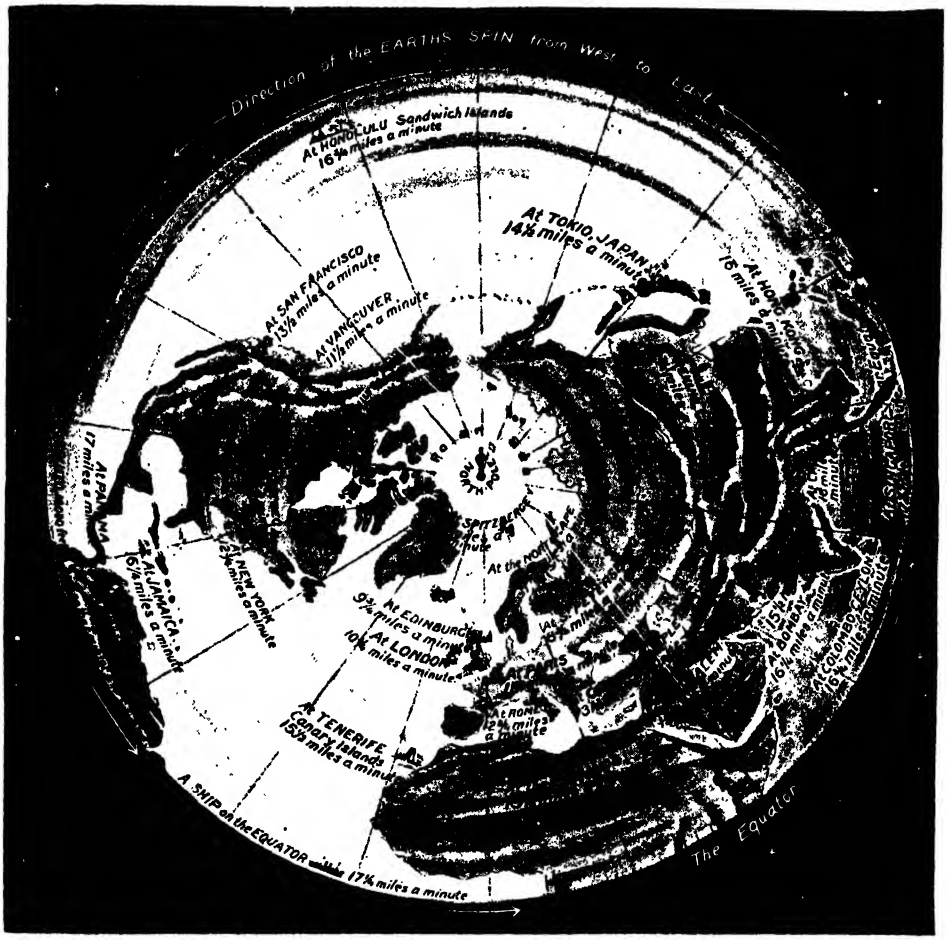
But observe now how the radiation of such a star, or any radiant body in motion, will produce remarkable consequences, utterly undreamt of until the last few years. The radiation-pressure in front of the body is greater than behind. Now, when a rifle discharges a bullet, and produces a greater pressure in front of it than behind, it "kicks," in accordance with Newton's third law of motion, which asserts that action and reaction are equal and opposite; and we can prove experimentally that the amounts of motion or energy in the direction of the bullet and in the direction of the "kick" are equal. The case of the rifle is long familiar; not so the case of any and every radiant body in motion. It is in just the case of the rifle, which discharges a pressure in front of it and must "kick," for we have proved that the radiation-pressure in front of a moving body must be greater than that behind it. Now, action and reaction are equal and opposite; and just as the rifle "kicks," or recoils, so a radiant body must be retarded by the reaction of its own forward radiation-pressure.

The Retarding of the Everlasting Circling of the Heavenly Bodies

Needless to say, Newton's first law remains true in principle; but in such a case as this, which is the case of unthinkable millions of celestial bodies, including the sun and all the bright stars, we must realise that "impressed forces" are altering their motion, though nothing from without be directly acting upon them. They are being retarded by the recoil from their own radiation-pressure. No doubt radiation-pressure is a force of very small intensity, compared with many that we have known longer; but if it be constantly producing any retardation, however small, in the

motion of moving radiant bodies, and if "the time is unending long," the cosmic results may be past our skill to imagine.

Fortunate are we small folk, standing on Newton's shoulders, thus to see further than was vouchsafed to him. We know radiation-pressure, as he did not, and one of its most notable consequences; and we are able to read his first law of motion, the enunciation of which was a great feat of scientific tude of that force, Newton laid down the principle whereby we can measure forces. If we measure the mass that they move, and the motion they induce, we have an absolutely trustworthy means of measuring their power. This is, indeed, the way in which we identify forces at all; and since Newton's second law will never fail us, we can compare and balance different forces by means of the motion they produce.



"THIS SPINNING WORLD"—A PICTURE-MAP SHOWING THE RATE AT WHICH VARIOUS PARTS OF IT TRAVEL ROUND ITS AXIS.

induction, and to see at once that it necessarily consorts with the greater law of the conservation of energy, which Newton did not quite know, but which is almost hackneyed to us.

Immensely important, from the point of view of practice, prediction, and research, is Newton's second law. In declaring that the change of motion produced by any force is strictly proportional to the magni-

Thus, to take familiar instances, we can measure the force of gravity, or the oppositely acting force of radiation-pressure. Many years ago Clerk-Maxwell declared that light must exercise a pressure, and declared its probable magnitude. That prediction has been verified within the last few years, when observers in Russia and the United States have been able independently to measure the force of radiation-pressure,

by observing the quantity of motion that it experimentally produces. The same principle, afforded by Newton's second law, enables us to measure the force of gravity, which he also revealed to us. We can observe the motion of the falling body, and see how many feet it falls in the first second, how many in the next, and so on; and from these observations, repeating and adding to those made long ago by Galileo, we can state the force of gravity at the surface of the earth, at the Equator, or at any other point we choose. We find—need it be said?—that gravity, constantly acting, constantly adds to the motion of a falling body. Thus, the longer it falls, the faster does it move, the greater is the force which gravity has imparted to it, and the greater, therefore, the force with which it strikes the ground. We should be able to explain, as many thoughtful people cannot, why it is more serious to fall from a great height than from a small one. In our part of the world a falling body increases its speed by about 32·2 feet a second in every second that it falls.

Motion Always the Result of the Combined Action of Many Forces

The second law further asserts that the change of motion produced by a force occurs in the line in which the force acts. This we have already seen illustrated in the case of the force of gravity, and in the objection to calling the onward force of a planet's motion "centrifugal," when it is not centrifugal, but acts in the line of the planet's motion at any moment, according to Newton's first law.

But the case of the planet reminds us that motion in the universe can very seldom—or, indeed, never—be due to the action of any one force. On the contrary, the motions we observe are in every case the result of the interaction of two or more forces. Even when we only identify two, as in the case of a planet's motion, there are really more at work. For instance, we ignore radiation-pressure in studying the motion of a planet; we ignore the gravitation of the stars; we ignore the attraction of the moon for the earth (if that be the planet we are studying), and of the planets for each other. Now, what happens in all these cases? Newton's second law teaches us that each and every force produces precisely the same effect, so far as it is concerned, as it would produce if it were acting alone.

Newton's second law declares that any force produces its due result, however many other forces be at work, and whether the body it acts upon be already in motion or at rest. This applies equally to the magnitude of the force and to its direction; and from this great consequences flow. For it enables us to add together any number of forces, of whatever magnitude, and acting in whatever direction, and to state unhesitatingly the exact speed and direction—or velocity, to use the technical term—which they will together impress upon a given body. This process we may call the "composition of forces."

The Calculation of the Net Magnitude of Natural Forces

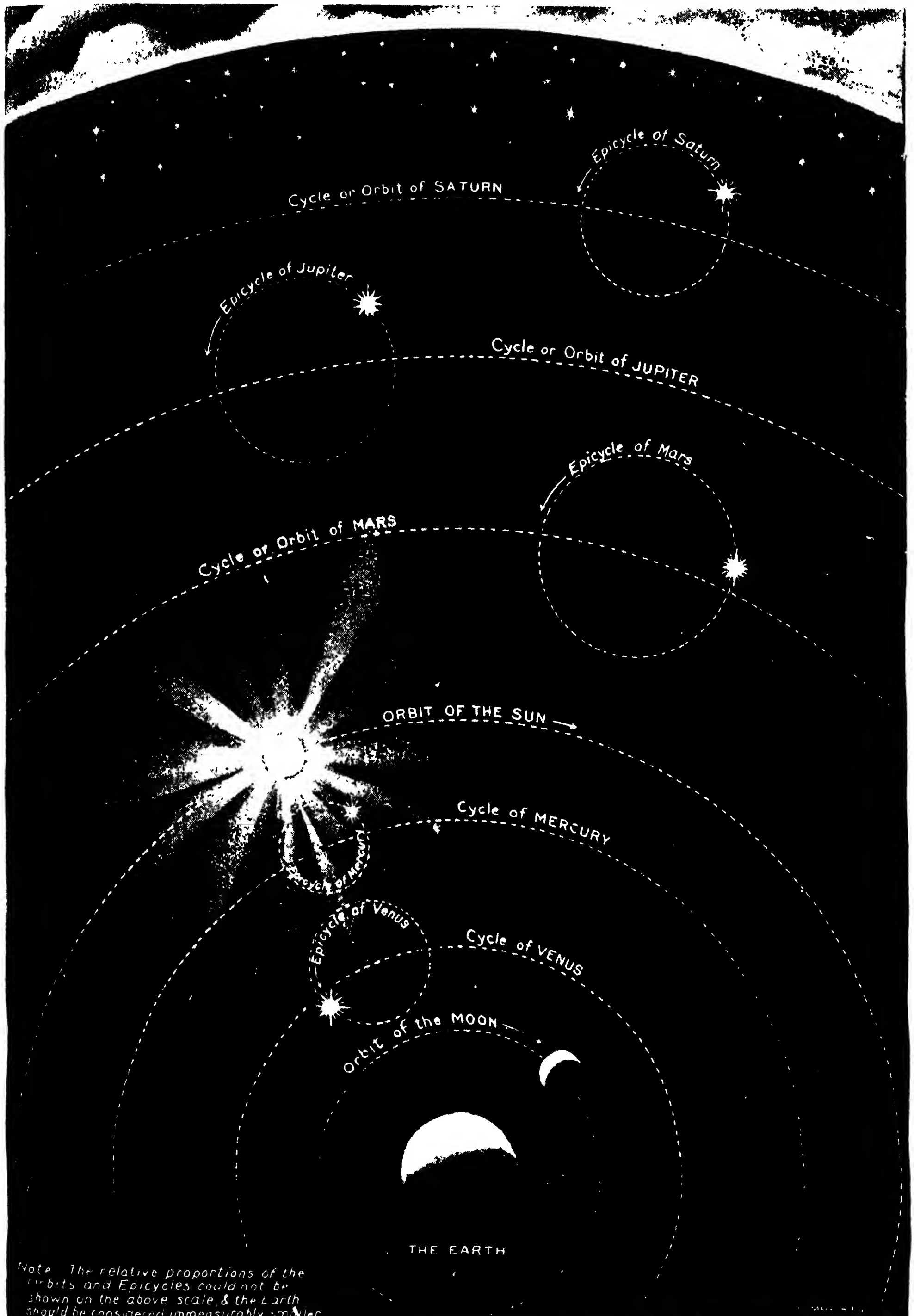
But the "resolution of forces" is no less important. We may observe a case of motion, say, of a moon or a cannon-ball, or a jet of water, and may be acquainted with one or more of the forces at work. We can now subtract them from the motion we observe, and thus, it may be, discover and measure forces hitherto unknown to us. It will thus be seen that Newton's second law is of scarcely less importance in science than the first.

The third law has already been illustrated in some degree, as it is involved in the recent study of radiation-pressure. There is no more familiar case of it than the recoil of a rifle when a bullet leaves it. We often see exactly the same thing when a cricketer is returning the ball from the outfield, and we notice his whole body driven backwards as the ball leaves his arm. Similarly, when we strike a wall it strikes us; and the force acting along a tense rope, such as a towing rope, acts equally throughout its length, and in both directions, the same force being directed upon the towers as upon the boat they tow, though we may find this at first difficult to believe.

The Infinite Complexity of Motion when Rotation is Added to Onward Movements

Such being the laws of motion, we may now observe that they apply equally to various forms of motion, which we must identify. When we were discussing absolute and relative motion, we were evidently quoting the cases of what is called "motion of translation," which is literally carrying-across. But though the motion of translation is what first occurs to our minds when we think of motion at all, there is a very different kind of motion which we call rotation. We are already familiar with bodies, such as the earth, which exhibit both motion of translation and motion of rotation, and the sun exhibits both also. Rotation is, of course, the motion of a body round a point within itself. We should not confound the earth's diurnal *rotation*, correctly so-called, with its annual *revolution*

WHEN ALL THINGS MOVED ROUND THE EARTH



Before the days of Copernicus and Galileo scientists explained the movements of the heavenly bodies by the system of Ptolemy depicted in this drawing. The earth was held to be stationary, while around it, once each day, revolved a vast sphere, to the inner surface of which the sun, moon, stars, and planets were fixed. The old astronomers, however, noticed an irregularity in this motion in the case of the planets, and elaborately calculated that each planet also revolved in a small circle, or epicycle, of its own. We now know that the earth is flying through space round the sun along a path defined by the laws of Kepler at the tremendous speed of about 15 miles a second, and impelled, guided, and controlled by Newton's three laws of motion.

round the sun. In studying concrete cases of motion, we find many that are extremely complicated—as, say, the motion of the tyre on a moving motor-wheel, or of the earth, or the sun, and, still more, of the moon, but in every case the motion can be resolved into the two great types above named.

Upon Newton's laws can be built the whole science of forces, which is properly known as dynamics. This is of equal importance in theory, where it leads us to the doctrine of the conservation of energy, or in practice, where it guides the astronomer and the engineer with equal certainty. The subject is truly universal, for precisely the same dynamic assumptions are made, and justify themselves, whether we are studying the motion of a "flying star," such as Arcturus, or an electron, too inconceivably minute for imagination.

But our survey of it is not complete unless we look at the work of one of Newton's most illustrious predecessors, whom Byron called "the starry Galileo with his woes."

Newton and Galileo, the Great Discoverers of Underlying Principles

If anyone be asked at random to describe Newton and Galileo, the answer would be that they were astronomers. We connect Newton with gravitation, and Galileo with the telescope. But neither of these men would have been what they were had they kept their eyes only on the heavens. Their work, not least their work in that field, depends upon their discovery of laws, first observed on the earth, which apply everywhere. Galileo is Newton's precursor in the foundation of the science of dynamics, which underlies all modern study and understanding of the balance and the destiny of the heavens.

We are familiar with the idea expressed as "centre of gravity," and can realise that the centre of gravity of a body must also be the centre of its mass—the point around which its mass is equally balanced. Observation on this subject was open to anyone who knew that bodies fall—that they possess weight or "gravity"—and Galileo was the pioneer here, as in many other respects, always illustrating the eternal principle of science that there is no authority but truth, accepting no one's word, not even Aristotle's, for any natural fact, but proving all things, and holding fast that which was good.

Above all do we owe to Galileo the discovery of the law of falling bodies. In our reference to the force of gravity, and the acceleration it produces in falling bodies, we have stated the very simple facts, but we have ignored the complications which beset them, and which Galileo removed.

The truth is that we have quietly set aside, as non-existent, the authority of Aristotle, which ruled the world with unquestioned sway for nearly two thousand years, until Galileo dared question it, and paid the tremendous price.

The Strange Mistakes of Ancient Philosophers which Galileo Boldly Overthrew

Let us just look at some of the ideas which our ancestors accepted from the mouth of the great Greek, and from which Galileo delivered us, thus preparing the way for Newton and the moderns, and taking many great strides along it himself.

Notwithstanding gravitation, a bladder rises in water, or a balloon in air. If we will think a little, we can now understand such cases, and see that they really illustrate the working of gravity; the denser air must be drawn nearer to the earth than the lighter gas in the balloon, which therefore rises, just as the air in the bladder is driven upwards to make room, nearer the earth, for the heavier water around it. Such motions as these depend upon the different density of substances, which we call their "specific gravity," and they not merely conform to the law of gravitation, but it would be no law if these apparently contradictory motions did not occur as they do occur.

But Aristotle's explanation was that certain bodies have "gravity," and fall, and others have "levity," and rise. All this is fundamentally false; and even if the terms and their contrast were true, the explanation would only be the explanation of the action of opium given by Molière's physician, that the cause lies in the "sleep-giving property" of the drug.

The Sound Discoveries that Seem to Contradict Our Everyday Experiences

From the tyranny and obstruction of these empty words Galileo delivered us.

He went further, for his mind never stopped when inferences were possible. Surely the descent of any body in a medium such as water depends, as regards its speed, upon the comparative density of the body and the medium in which it moves. Suppose, then, that we could observe bodies falling where there was no medium? "I have thought," said Galileo, "that if the resistance of the media be wholly taken away, all matter would descend with equal velocity." This was a tremendous assertion; and if we suppose it obvious, the chances are

that we have not realised it. But the experiment can be made. Every day we observe that different forms of matter fall at different speeds. But if we take a long tube, remove the air from it as far as possible, and then allow a sovereign and a feather to fall from end to end of it, we find that they arrive at the same moment.

We must now perceive that, when we asserted the law of gravitation, and when we stated the force of gravity, as measured by the motion it can induce, we were making very large and general assertions, which by no means agree with the superficial appearance of things. In that statement of ours, we said nothing about the consistence or the density of the falling body, but asserted a certain speed to be true of all falling bodies, whether their shape or consistence or density be after the fashion of a feather or of a sovereign. Perhaps we may now realise our debt to Galileo, whose work was indispensable for the subsequent enunciation of those constant and universal laws which now seem so simple to us.

Galileo's Experiment from the Leaning Tower of Pisa that was Never Forgiven

But there was another question. If we take two bodies of the same consistence and density—which is obviously a different problem from that of the feather and the sovereign—and if we make one of them twice as massive, or as heavy, as the other, how will they then fall in comparison with each other? In our foregoing generalisations, we have said nothing of the massiveness of bodies falling to the earth. We said that they fall with a certain, exactly measurable acceleration, due to gravity, and varying according to the force of gravity at different parts of the earth or on different planets, and we have ignored the fact that bodies differ in massiveness. The fact is irrelevant, as Galileo proved, to his cost and our gain.

Aristotle had said otherwise. The falling was due, in his view, to the gravity or heaviness of the falling body. If we double its gravity or heaviness, it should fall twice as fast, he said. Neither he nor anyone else tried the experiment, which is surely as simple and easy as can be. Aristotle had said so, and for nearly two thousand years that was enough.

Galileo, then at Pisa, declared that, but for the small difference due to the disproportionate resistance of the air, the two bodies, of different weight, would reach the ground at the same time. The followers of Aristotle—everyone, that is to say—laughed at him. "But Galileo was not to be repressed, and determined to make his adversaries see the fact as he saw it himself. So one morning, before the assembled University—professors and students—he ascended the Leaning Tower, taking with him a ten-pound shot and a one-pound shot. He balanced them on the overhanging edge, and let them go together. Together they fell, and together they struck the ground."

The champions of scientific orthodoxy never forgave him, and his ultimate doom was already pronounced when those weights struck the ground together.

The Reason Why Galileo was Right and Why Aristotle was Wrong

But undoubtedly there is a difficulty in understanding, at first, why this experiment should have resulted as it did. Surely, we say to ourselves, the force of gravity is greater when it is exerted between the earth and a ten-pound shot than when between the earth and a one-pound shot; and, if so, ought not the resulting motion to be proportionate, according to Newton's second law? Undoubtedly the reasoning is correct so far: greater force is exerted in the former case, and more motion should be the result. But quantity of motion depends upon mass as well as velocity. We express it as momentum, which is mass multiplied by velocity And in this case the greater force is justified, for it is moving a proportionately greater mass; and the velocity is thus the same in both cases.

Galileo was not only a great mathematician and a great experimenter, but he was also a master of the deadly weapon of ridicule, which is a great servant of truth, but never pardoned in those who wield it.

What a Great Philosopher Inferred from the Idle Swinging of a Cathedral Lamp

One other discovery of Galileo's regarding motion, and we may pass onwards to the skies and their contents. It was that a vibrating pendulum performs its movements in the same time, whether they be large or small; hence the possibility of measuring time therewith. And as the story goes that Newton, at twenty-three, saw an apple fall, and guessed his great discovery, so they say that Galileo, at eighteen, in the cathedral at Pisa, watched a great lamp swing from the roof of the nave, timed the oscillations by means of his only watch—his pulse—and found them performed in equal times, whether they were large or small. We all have eyes and pulses, but do we use them so?

THE FLINTY SKELETONS OF ANIMALS

These beautiful structures, magnified 25,000 times, are the skeletons of radiolarians, minute unicellula animals that live in the sea. Their skeletons are composed of silica, and form most of the deep se ooze that has been dredged from depths of over three miles. This photomicrograph is by Mr. J. J. Ward

ELEMENTS NOT METALS

The Changing Dance in which Cleansing Oxygen, Surly Nitrogen, Flighty Hydrogen, Unfriendly Chlorine, Sturdy Silicon, and Powerful Carbon Play

THE INVISIBLE ALLIES OF PROGRESS

Most of the elements are metals, but among the non-metallic elements there are some of great importance. Among the most important may be mentioned the gases oxygen, nitrogen, hydrogen, and chlorine, and the solids silicon, sulphur, phosphorus, and carbon.

Oxygen, the most widely distributed of all the elements, is a colourless, odourless, and tasteless gas. It forms more than 21 per cent. by weight of the atmosphere, eight-ninths of the water of the world, nearly half of the material in the earth's crust, and about 20 per cent. of animal and 40 per cent. of vegetable tissues. Oxygen is essential for the support of animal life, as it is the only gas capable of supporting respiration. Oxygen does not burn, but it is the greatest supporter of combustion, and it unites with nearly all elements forming oxides. Some of these oxides are stable and some unstable; some, like the oxides of sodium and potassium, are so stable that they can only be decomposed with difficulty, and were long thought to be elements.

Oxidation is usually associated with the production of a good deal of heat, and, in many cases, as in cases of ordinary combustion, also of light. The oxidation of hydrogen gives rise to water, and great heat is evolved in the process. On this principle depends the oxy-hydrogen blow pipe. When a mixture of granulated aluminium and iron is set on fire, the aluminium oxidises, and in the process of oxidation produces a temperature of 3000 deg. centigrade or more. On the other hand, the heat produced by the slow oxidation of iron, such as rusting, is not noticeable; and the heat produced by the oxidative process of respiration in the human body is usually only 98·4 deg. Fahrenheit. Oxygen can be liquefied at a temperature of −183 deg. centigrade, and the liquid freezes at −212 deg. centigrade.

Nitrogen occurs free in the atmosphere, of which it forms three-quarters by weight; and it also enters into the formation of all living tissues. Like oxygen, it is a gas without colour, odour, or taste, but, unlike oxygen, it does not readily enter into combination with other elements, and usually requires a good deal of provocation before it joins. Thus, nothing short of terrific heat or a lightning flash, or the mysterious processes of life, will link together the atmospheric oxygen and nitrogen, and even when nitrogen does form compounds it is very loosely linked.

But the laziness and looseness of nitrogen give it quite a sensational place in chemistry. It is essentially the element of explosions: it gives up its oxygen readily to other elements, hence constant violent divorces and remarriages. In combination with oxygen and hydrogen it forms nitric acid, also known as aqua fortis, which is largely employed in the preparation of explosives. Gunpowder, nitro-glycerine, cordite, and the other explosive compounds of nitrogen owe their explosiveness to the fickleness of nitrogen. Life itself is largely a series of little explosions with rearrangement of molecules, and nitrogen is the moving spirit of these changes.

The importance of nitrate of sodium as a fertiliser of wheatfields we have already noted. Nitrous oxide, a compound of two atoms of nitrogen with one of oxygen, is the well-known anæsthetic known as laughing gas.

Another very widely distributed element in Nature is hydrogen, which forms a ninth by weight of all the water in the world, and is the lightest gas known. Hydrogen is also a colourless, tasteless, odourless gas. In oxygen, as we have already said, it burns, forming water and producing great heat. It may be set

free from the water again by decomposing the water by passing a current of electricity through it. Hydrogen can be liquefied at a temperature at -253 deg. centigrade, and the liquid solidifies at -264 deg. centigrade. In combination with sulphur it forms the evil-smelling gas sulphuretted hydrogen; in combination with sulphur and oxygen it forms the acid known as oil of vitriol or sulphuric acid; and in combination with chlorine it forms the acid known as hydrochloric acid. Owing to its lightness it is used for filling balloons.

Chlorine, the Gas that Has Powerful Bleaching Properties

Now let us look at another gas, called chlorine. Physically it is very unlike the previous gases. It has colour, and taste, and smell. In colour it is yellowish-green, it has an acrid taste, and an unpleasant, suffocating odour. Luckily it does not occur free, and almost the whole lot of it is tied up with sodium in the form of common salt. For hydrogen it has an intense affinity, and joins it explosively, forming hydrochloric acid if a mixture in equal volumes be exposed to the sun's rays. The explosion is due to the great heat generated by the conjunction causing a sudden expansion of the surrounding gases. It would be a very different world if all the chlorine at present in conjunction with sodium had joined hydrogen to form hydrochloric acid.

The metals have a particular liking for chlorine, and even gold, silver, and platinum, that will have nothing to do with oxygen, form with chlorine salts called chlorides. Some metals such as antimony, if powdered, will actually burn and become incandescent in chlorine, and sodium will burn in chlorine, forming common salt. Sulphur and phosphorus, and the majority of non-metals, also burn in chlorine. Chlorine is a very powerful bleaching agent; and if it be passed over dry hydrate of lime at the ordinary temperature, a mixture known as bleaching powder, or chloride of lime, is produced. Closely allied to chlorine are the liquid bromine and the solid iodine, whose salts, called bromides and iodides, are well known in medicine.

The Element Silicon, of which One Quarter of the Earth's Crust is Composed

Of all the solid non-metals, silicon is the most plentiful, forming as we have said, about 25 per cent. of the crust of the earth. But it never occurs free in Nature, and it is a matter of the greatest difficulty to isolate it in a pure state. When isolated it occurs either as a dark brown powder or in crystalline form, according to the way in which it is prepared. In Nature it occurs chiefly as the oxide of silicon, or *silica*, as it is called, which is found either free, or in combination with metallic oxides as silicates. Quartz or rock crystal is the chief form under which silica is found free and almost pure, while sand is also mostly composed of silica, with a greater or smaller amount of impurities.

Silicon has played a most interesting and curious part in the progress of civilised man. No other element perhaps has done more to raise man from savagery, and to enlarge his visual and mental horizons. Thus flint, or silex, which is practically pure silica, was the first substance from which primitive men made his first tools. Flint is a rock of organic origin, which is mostly found scattered in irregular masses through chalk and limestone. Flint is very hard, but it can easily be worked, when it yields sharp, fine edges.

How the Pebbles of the Seashore were Won from the Sea-Water by Animals

Strangely enough, it began its civilising career in certain ancient sponges represented nowadays by such sponges as Venus' Flower-Basket, and others. It did not begin by teaching savage man to wash his face. These sponges have not a skeleton made of soft, horny substance suitable for ablutionary purposes; their skeleton consists of a delicate meshwork of glassy-like fibres and spicules made of silicic acid, which is the substance otherwise known as opal. These sponges, which grew in great numbers on the deep-sea ooze of the ancient seas—just as they do in the seas of our own time—extracted the silica from sea-water, and wove it into beautiful, basket-like forms. In time these were covered up by the accumulating chalk; and by some processes, the details of which are not yet thoroughly understood, it became compacted into the hard lumps known as flints. When we consider that for the formation of one ounce of spicules an average-sized sponge uses all the silica in a ton of sea-water, we can imagine how much pains Nature took to make these concretions, yet she made plenty of them. The pebbles in ordinary gravel are simply water-polished flints, and every chalkpit has layers of them. Flints are simply pebbles with an interesting past millions of years ago, and to see them one would not guess either that they had a past or a purpose.

When primitive man found these flint pebbles, he shaped out of them his first

tools, as well as his first weapons for attack and defence. He made fish-hooks of them, and caught fish with them. He made hatchets of them, and cracked his neighbour's skull with them. And so he became man the tool-maker, and stole a march on his monkey cousin, and inaugurated the Stone Age. But he did still more wonderful things with this lump of silica: by the impact of flint and steel he was able to produce a spark, and so he created fire, and was able to warm his toes, and cook his food, and smelt his metals. Of silica he probably made his first tools, with silica he perhaps made his first fire, and in silica he left us the first records of his appearance in the world. As Mathilde Blind has put it in lines well known—

With cunning hand he
 shapes the flint,
He carves the bone
 with strange device,
He splits the rebel rock
 by dint
Of effort—till one day
 there flies
A spark of fire from out
 the stone,
Fire which shall make
 the world his own.

A DIAMOND BEING BURNT IN OXYGEN

But silica has meant still more to man. It gave him fire, and with fire he tortured it into wonderful shapes, with noble uses. With fire he made of it a window into infinity, for with fire he melted it, and, melting it, made glass, and by glass he has wrested secrets from the sun, and the moon, and the stars, and has hunted the secret of life down to its last redoubts in the microscopic cells. Without glass we should be centuries behind in chemistry, and more than centuries behind in astronomy, and bacteriology, and biology. Man never did more wonderful feats than when with glass he found the elements in the sun; than when with glass he found his infinitesimal foes, the microbes of disease, and than when with glass he discovered the little nerve-centres in his brain in which are hid the mystery of consciousness.

Glass is made by melting sand which contains silica, together with lime and soda or potash, or lead and soda and potash. According to the mixture the glass varies in character, but silica is the essential ingredient, and the more silica in the sand the better the glass. By mixing in certain metallic oxides such as oxide of iron, protoxide of copper, oxide of uranium, oxide of gold, sesquioxide of uranium, glass may be tinted various hues.

Seeing the qualities of silicon, it is not surprising to find that it is the basis of many gems and precious stones—amethysts, cairngorms, jaspers, onyx, chalcedony, agate. Opals are almost pure silicic acid. In combination with aluminium, silicon is the basis of topazes, garnets, and beryls, and in combination with sodium it is the basis of lapis lazuli. Clay is also a silicate of aluminium, and the purest form in which it is found is kaolin, or china clay, from which the finest china is made.

The straw of the grasses is held in shape mainly by the silica it contains, and in the knots of bamboos there is usually a deposit of the same substance. Certain petrifying springs owe their property to the large amount of silica they hold in solution.

Among the non-metals, the remarkable element phosphorus must be mentioned for, though it never occurs free in Nature it is widely distributed in combination with other elements, and has very important biological functions. Thus the protoplasm of all living cells, animal and vegetable, contains phosphorus.

It is usually extracted from the calcium phosphate of bones, or from minerals which contain phosphates, and it occurs in two forms which have different physical properties. In the one form, known as yellow or ordinary phosphorus, it is a transparent, waxlike substance, yellowish or colourless, almost insoluble in water, fusing at 44 deg. centigrade, and very inflammable, taking fire at 60 deg. centigrade. It oxidises very readily in the air, and becomes phosphorescent. In the other form, known as red phosphorus, it is a hard, reddish-brown, opaque substance, which does not oxidise

at ordinary temperatures, which does not become phosphorescent, which fuses only at 360 deg. centigrade, and which is not poisonous.

The soil contains, as a rule, from one to five parts per thousand parts of phosphorus, reckoned mostly as phosphoric acid, without which no plant will thrive. The phosphorus in plants passes in turn into the tissues of animals, and plays a great part in the structure of their bones, and in the composition of their nervous tissues.

Phosphorus, the Great Vitaliser of Brain and Nerve

The brain-cells and nerve-cells have indeed been called highly phosphorised fats in a weak salt solution; and there is a German saying to the effect that without phosphorus there is no thought. This is probably going too far, but there is no doubt phosphorus is conducive to vital activity; and one of the chief advantages of standard bread is that it conserves the phosphates in the wheat which are sacrificed in the preparation of white flour.

As a light-bringer, phosphorus on the head of a lucifer match has quite superseded the old tinder and flint. The head of the ordinary lucifer match is composed of ordinary or yellow phosphorus, and some oxidising substance, such as manganese dioxide, or nitre—that is, potassium chlorate. The heat generated by rubbing sets the phosphorus on fire, and it burns in the oxygen it derives from its oxidising companions. The safety matches contain no phosphorus, but merely a mixture of combustible substances such as antimony sulphide with potassium chlorate, while the phosphorus—in the form of red phosphorus—is on the striking surface of the matchbox.

The Sulphur that Forms the Acid So Valuable in Modern Industry

Sulphur, another non-metallic element, must also be mentioned, for it is very widely distributed in Nature, both free and in combination. There are rich deposits of free sulphur in Italy, the United States, and Japan. It is usually purified by distillation, and is given to commerce either in form of a fine powder, known as flowers of sulphur, or in cylindrical rolls. Like phosphorus, it may be prepared in two forms, differing in their physical characters.

Sulphur rivals chlorine and oxygen in its sociability, and if it be heated it will enter into combination with nearly all the elements. At ordinary temperatures, however, it does not combine. With hydrogen it forms the offensive gas sulphuretted hydrogen, which gives the characteristic odour to rotten eggs and to sulphur waters. With oxygen and hydrogen it forms the useful acid sulphuric acid, which is used in the preparation of sodium carbonate, in the manufacture of nitric and hydrochloric acids, in the extraction of stearin and stearic acid from tallow, and for a hundred other industrial purposes. "It would be difficult," says Mendeléeff, "to find another artificially prepared substance which is so frequently applied in the arts as sulphuric acid." All vegetable proteids contain sulphur, and it forms an essential constituent of animal bodies.

Finally, we come to carbon, which in some respects is the most distinguished of all the elements. It occurs in three pure forms which outwardly are very unlike each other, namely, as charcoal, graphite, and diamond. Carbon is one of the most prominent elements in the sun, and to it we chiefly owe the radiancy of the sunlight. In ordinary artificial light it is little particles of solid unfused carbon that radiate the light; and if we burn up all the carbon quickly and completely, as in a Bunsen burner, the flames become hotter and cease to give light.

The Vapour from the Sun that Gives Our Earth the Glories of Daylight

In the blazing furnace of the sun the carbon is volatilised so that it can radiate no light; but as it flies away in vapour form from the sun it reaches cooler regions, and it solidifies into little particles, just as rising water-vapour grows to clouds in our upper atmosphere, and the little particles glow like the sticks of carbon in an arc lamp, and, lightening in turn the little particles of dust in our atmosphere, give us the glories of daylight. "When we consider," says Sir Robert Ball, "that millions of millions of square miles on our luminary are covered with clouds, of which every particle is so intensely bright, we shall perhaps be able to form some idea of that inimitable splendour which even across the awful gulf of ninety-three millions miles transmits the indescribable glory of daylight."

In combination, carbon forms the well-known gas carbon dioxide and the two very important metallic compounds, calcium carbonate and sodium carbonate. In combination, too, it forms the basis of that mighty source of energy known as coal, and of that other wonderful source of energy known as food. Its combinations, however, are innumerable; it is the great centre of the organic compounds, and of the

ırtificially prepared synthetic compounds which are already legion. So numerous, ndeed, are carbon compounds that there is now a special branch of chemistry known as organic chemistry, or the chemistry of the hydro-carbons and their derivatives.

It seems almost incredible that diamond ınd charcoal should be the same substance, he one opaque, black, common; the other ransparent, glittering, precious. Yet they ıre undoubtedly composed of the same element. With wonderful scientific penetraion, the great Sir Isaac Newton surmised hat the diamond, since a body with strong efractile powers, would probably be found combustible. Newton was right; the diamond is combustible at high temperaures, and when it is burnt it produces carbon dioxide gas just as charcoal does. t would be quite possible to ıerate water with carbon lioxide derived rom diamond, ınd the aerated water would be exactly the ame as water ıerated with carbon dioxide lerived from carbonate of calcium or from any other source. The naterial of dianond is carbon, ınd nothing out carbon.

QUARTZ CRYSTALS, THE PUREST FORM OF SILICA

How comes it, then, that physically charcoal and diamond are so unlike? It is simply an example of molecular difference, such as also gives us varying forms of sulphur and phosphorus. The nature of any substance depends not only on the element or elements composing it, but also on the molecular arrangement of the elements. Diamond is different from charcoal simply because its molecules of carbon are differently built up.

We find this difference in physical properties with identity in chemical composition, not only in pure carbon, but in many compounds of carbon. Thus, benzonitrile and phenylisocyanide are each composed of seven atoms of carbon, five of hydrogen, and one of nitrogen. Yet the first is non-poisonous, with the pleasant odour of bitter almonds, while the second is poisonous, and has a very offensive smell. It is plain that such a difference must depend on different arrangements of the atoms in the molecule.

Led by such suggestive facts, chemists began to try to discover the position of the atoms in the molecules of the various substances, and to represent the supposed position by a similar disposition of their symbols on paper.

In this way the new and very important branch of chemistry known as stereochemistry, which deals with the special relations of the atoms in the molecule, was born. We can now in many cases picture to ourselves the position of the various atoms composing a compound molecule, which is surely one of the greatest feats of scientific imagination.

But this is somewhat of a digression. Let us now return to the diamond, and give it a little separate consideration. As we have said, it consists of carbon, and differs from pure charcoal or pure soot merely in the arrangement of its atoms of carbon in the molecules. Its radiancy, its hardness, its durability has made it the king of gems, and diamond-mining and diamond-cutting are big and important industries.

In spite of the commercial and social value of the diamond, the facts of its geological genesis are unknown. All we do know is that ordinary carbon can be changed into diamond by great heat and pressure. Minute diamonds can be produced artificially in the following manner: pure iron is mixed with carbon and packed in a carbon crucible, and the crucible is put in an electric furnace and subjected to a temperature of 4000 deg. centigrade. At this temperature the iron melts and absorbs carbon. After a few minutes' heating, the crucible with its contents is plunged in cold water. The outer layer of iron solidifies, and the

expansion of the iron in the centre as it cools (for iron expands as it cools) is checked by the solid outer layer, and in this way tremendous pressure is produced. Under this pressure the dissolved carbon separates out in a hard, transparent, dense mass, where—after several other chemical operations—are found graphite, minute black diamonds, and also minute colourless diamonds.

It is probable, therefore, that diamonds were formed at a great heat, and under great pressure in masses of molten iron having carbon in solution, but this is about all we do know. But a very interesting theory was propounded some years ago, namely, that the diamonds were brought to earth embedded in meteoric iron, and that the "pipes" in which diamonds are found are simply holes made in the ground by the meteoric masses. The theory is bold, but it may be to some extent correct, for diamonds, both black and transparent, have been found in meteoric iron collected in the Cañon Diablo, Arizona, in Mexico, and in other places. Sir William Crookes says it is certain that "on more than one occasion a meteorite freighted with jewels has fallen as a star from the sky."

HIGHLY MAGNIFIED POINTS OF A SPONGE

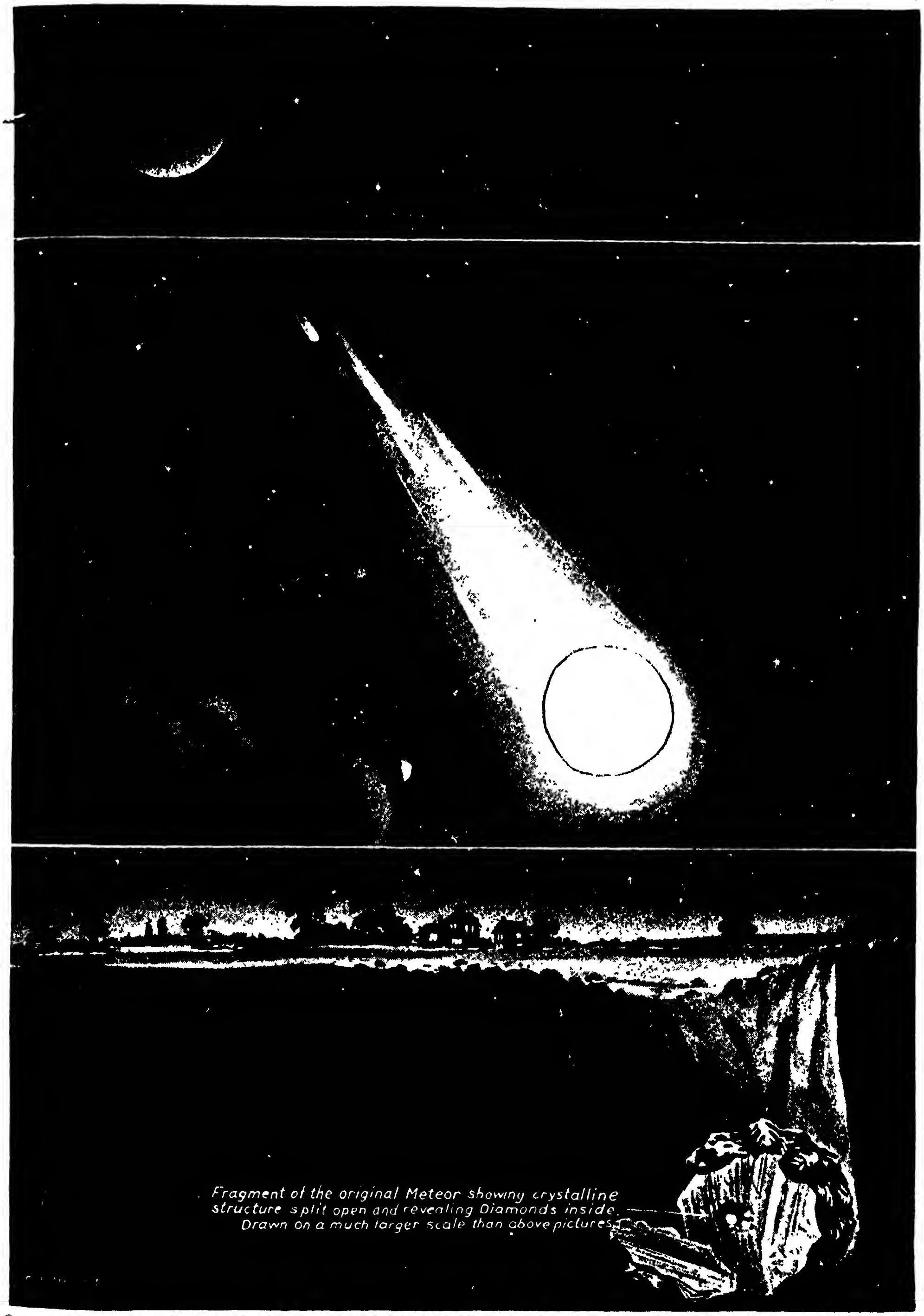
Between charcoal, which is soft carbon, and diamond comes graphite; and though graphite does not possess the diamond's beauty, it may easily be maintained that it has been of more true value in the world, for of it is made the common lead pencil, wherewith perhaps a good many thoughts, more imperishable even than diamonds, have been given to the world. Graphite occurs free in Nature, mainly embedded in old crystalline rocks, like gneiss, schist, and granite. It is a black, opaque substance, and it is one of the softest of minerals. Graphite is greasy to touch, and it soils everything with which it comes in contact. It is used for making crucibles, for polishing ironwork, for lubricating machinery, and for many other useful purposes.

Whether graphite be more valuable than diamond or not, there is one compound of carbon that is certainly of much greater value—we refer to the wonderful black diamond commonly known as coal. We have already dealt in other parts of this work with coal, so that we will be content to discuss it here only in the most general way.

The greater part of the coal known to the world is a product of the jungles and forests of the Carboniferous Period. Indeed, the Carboniferous Period derives its name from the part it played in preparing coal for mankind. In this period the air was probably laden with carbon dioxide, the climate was moist and warm, and under these favourable conditions vegetation flourished with tropical luxuriance, and jungly forests covered the face of the earth. Our familiar club-mosses were represented by huge trees, called by botanists Lepidodendrons, which attained a height of forty or fifty feet; plants of the horsetail order, which have been named Calamites, grew to the height of twenty feet; other trees, which have been named Sigillarias, thrived exceedingly, reaching even seventy feet in height: and there was an abundance of ferns and tree-ferns.

In no other age—said Hugh Miller, in a lecture in London—did the world ever witness such a flora; the youth of the earth was peculiarly a green and umbrageous youth, a youth of dusk and tangled forests, of huge pines and stately araucarias, of reed-like calamites, the tall tree-fern, the sculptured sigillaria, and the hirsute lepidodendron. Wherever dry land, or shallow lake, or running stream appeared, from where Melville Island now spreads out its ice wastes under the star of the Pole to where the arid plains of Australia lie solitary beneath the bright cross of the South, a rank and luxuriant herbage cumbered every foot-breadth of the dank and steaming soil, and even to distant planets our earth must have shone through the enveloping cloud with green and delicate ray. Of this

DO DIAMONDS FALL FROM THE SKY?



On this page the artist illustrates the theory, propounded by Sir William Crookes, that diamonds sometimes fall from the sky. In the top picture a meteor is shown travelling in space; in the second it is seen entering the earth's atmosphere, the tremendous speed at which it travels—often 40 or 50 miles a second—igniting it. The meteor may be composed of a variety of about twenty materials, and the more combustible of these probably go off as gas, causing the trail of light that follows in the path of a meteor. The more resistant of these elements, however, reach the earth; and the great heat generated during the passage through the atmosphere, the rapid cooling and the tremendous internal pressure that follows would appear to be conditions favourable to transforming its carbon into the crystal form of diamonds. Diamonds have actually been found in meteors, as in the famous fall of Nowa-Urei, in Russia, on November 22, 1886

extraordinary age of plants we have our cheerful remembrancers and witnesses in the flames that roar in our chimneys when we pile up the winter fire, in the brilliant gas that now casts its light on this great assemblage, and that brightens up the streets and lanes of this vast city; in the glowing furnaces that smelt our metals and give moving power to our ponderous engines; in the long, dusky trains that with shriek and snort speed athwart our landscapes; and in the great cloud-enveloped vessels that darken the lower reaches of your noble river and rush in foam over ocean and sea.

In the greenery of this forest world were scorpions, and spiders, and centipedes, and locusts, and cockroaches, and white ants, and mayflies, but no large animals except the amphibians known as labyrinthodons. But the land with its jungles and forests subsided under the sea; the vegetation was covered up with silt, and under the combined action of pressure and moisture the vegetable matter, fern and tree, was converted into coal. We see the same process taking place nowadays in peat-bogs all over the world. In coal we find well-preserved remains of tree-trunks, and ferns, and club-moss spores, which plainly tell the interesting history of its origin. In time the coalbed, covered with sand or chalk, was raised above the sea; and again, perhaps, the land became clad in rich vegetation—ferns, Calamites, Lepidodendrons, Sigillarias—to again be plunged under the sea. And so seam after seam of coal might be formed.

A FOREST IN THE CARBONIFEROUS AGE

The change from wood to coal consists essentially in the elimination of nearly all the constituents of wood except the carbon; and it has been calculated that this elimination is attended with the loss of about 75 per cent. in weight. The seams of coal are very thin compared with the whole thickness of the carboniferous strata. The thickness of the carboniferous strata in South Wales has been estimated at about 8000 feet, and the aggregate depth of the various coal seams at 40 feet. In North Lancashire the same proportions are found. In Nova Scotia, in coal-bearing strata, more than three miles thick, eighty seams of coal have been counted, but none are more than five feet in thickness, and many but a few inches thick.

Still, the whole acreage of the coalfields is great. In Great Britain alone there are nearly 6000 square miles of coal, and in North America over 200,000 square miles. The United States coalfields have a total area, exclusive of the Alaskan mines, of nearly thirty times those of the United Kingdom.

The great importance of coal lies in the fact that it represents power which man can use for his own ends. The rays of the sun beating for countless ages on the luxuriant vegetation of the carboniferous times, gave that wonderful green matter, chlorophyll, sufficient force to tear the carbon from the carbon dioxide of the atmosphere, and to build it up into vegetable tissues. Then the mighty forests sank to the bottom of the sea, and new energies came into play. The vital energies of the microbes of decay, the solvent energies of water, the tidal energies of the moon, the gravitative energy of the earth, all conspired to break up the vegetable tissue again, and to convert them into a hard

substance containing a large amount of carbon and small amounts of hydrogen and oxygen. This compound, so made, is pre-eminently oxidisable, and oxidation means heat, and heat means energy.

We set the coal on fire, the carbon and hydrogen in it oxidise and burn and give forth heat, and with the heat we can transform water into steam, and with the force of the steam we can move the mighty turbines of the Mauretania or the flashing pistons of the Flying Scotchman. When George Stephenson was asked what force drove his locomotive, he said: "Bottled-up sunshine;" and though more energies than the energies of the sun went to make the coal, yet it was the sun, millions of years ago, that *began* to make it.

All over the world, wherever we find coal, we find the record of the work of a tropical sun; and Sir Ernest Shackleton's discovery in the Antarctic zone of coalfields with seven distinct seams of coal tells us that formerly green jungles and forests flourished under a blazing sun where now there are only ice and snow and howling blizzards.

A CLUB-MOSS OF TO-DAY

The energy contained in coal is enormous. A pound of good coal—that is to say, a piece about as big as a man's fist—in combining with oxygen, radiates heat equivalent to the energy of lifting about 10,000,000 pounds a foot high, or to the lifting of one ton to the top of Ben Nevis. Put otherwise, one pound of coal will do as much work as a powerful horse can do in five hours, remembering that the work done by a horse in one hour is nearly two million foot-pounds. These estimates refer to the potential power of coal; but when we actually attempt to turn its heat into mechanical energy we find that we can utilise only about one eighth or ninth of its potential energy. In the whole world there are at least seven million million tons of coal available, representing, therefore, a terrific store of potential energy.

It has been said that the ironmaster is the world-master, but the coalmaster is the ironmaster, for without coal no nation can master iron. On coal-fires and boiling water almost all the great industries depend, and in England alone there must be a hundred thousand steam boilers at work.

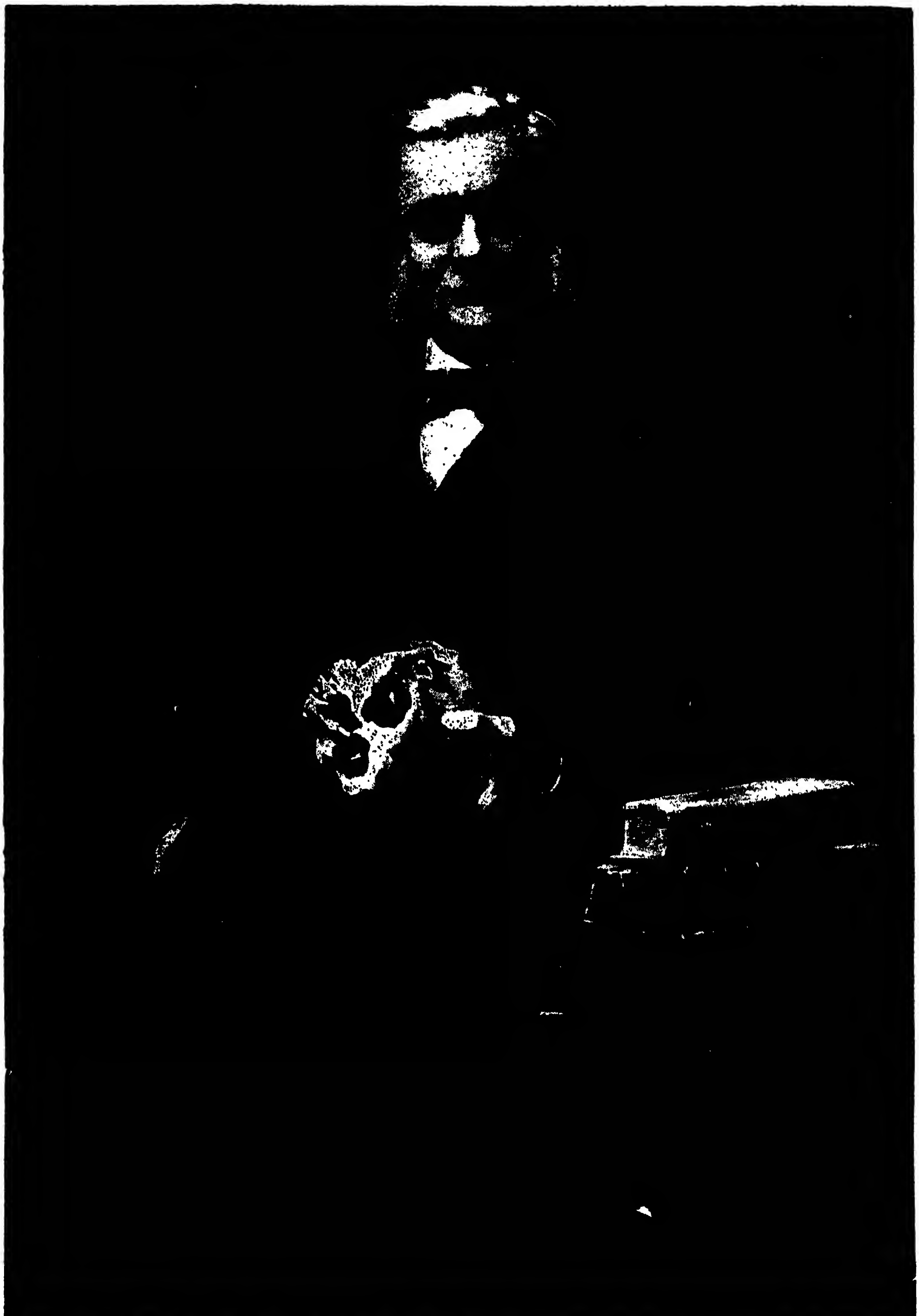
But coal has given the world more than heat, and the work that heat implies: it has given the world light. Ordinary gas is coal-gas on fire, and even the electric light is the power of coal transformed into light-waves. The coal relationships of electric light are particularly interesting, for the electricity is derived from the heat produced by oxidation of coal-carbon, and passing through carbon again—the carbon of the carbon film—is converted into heat and light waves. So we have a circle from hot carbon through electricity, to hot carbon again.

Nor yet have we exhausted the uses of coal, for it also gives us innumerable chemical products. Fifty-five years ago, Sir William Perkin extracted from coal-tar a beautiful mauve dye, starting a new branch of coal-tar chemistry, which has now grown to a huge industry. From coal-tar we now extract not only an enormous number of dyes, but also delicate perfumes that rival the violet and the rose, delicious flavours that appeal to the epicure's palate, explosives powerful enough to blow up a battleship, and drugs of all sorts—all from the decayed vegetation of primaeval forests.

Nor must it be forgotten that carbolic acid, a coal-tar product, pioneered in Lord Lister's hands aseptic surgery, and has probably saved more lives than any other chemical compound under the sun.

When we consider that carbon is probably the chief element in living tissues, that it is the main source of solar light, that it is the basis of coal and the coal-tar products, and of petroleum and petrol, we must surely consider it the most interesting and accomplished of all the elements.

A VALIANT CHAMPION OF EVOLUTION



PROFESSOR HUXLEY, FROM THE PAINTING BY THE HON. JOHN COLLIER, NOW IN THE NATIONAL PORTRAIT GALLERY, LONDON

CREATIVE EVOLUTION

How Life Climbs and Creates, but Most Swiftly Along the Open Road of Human Intelligence

THE LOST BATTLES OF DOUBT

FIRST as to names. Organic evolution is the correct modern term for that branch of the doctrine of universal evolution which deals with living beings or organisms. We might equally well speak of the development of one species from another; and years before modern ideas were made irresistible by the work of Darwin, Herbert Spencer was writing on the "development hypothesis." Later, he introduced the word "evolution" in its modern sense; and to-day we conveniently employ "development" for the history and changes of individuals, and "evolution" for the history and changes of races. The doctrine of the transformation of one species into another is generally termed "transformism" by the French, who can claim the great pioneer Lamarck, and have some title to use what word they please, but "evolution" is better.

"Darwinism" was long used as synonymous with the doctrine of organic evolution, because the Darwinian theory gained for it great acceptance; but the doctrine of organic evolution is vastly older than Darwin, and the term "Darwinism" is correctly employed only to indicate the particular theory advanced by Darwin to explain the process of organic evolution. Similarly, Neo-Darwinism, a term in wide use to-day, is the theory that the special factor of evolution, discovered by Darwin, is all-sufficient; and it is opposed to Neo-Lamarckism, the theory that the factors of evolution asserted by Lamarck are the essential ones. Each and all of these, together with Mendelism and Weismannism, are comprehended in, seek to contribute to, and assume the truth of organic evolution, but this doctrine is ages older than, and would survive, any of them.

In this department of universal evolution, as elsewhere, the old-new doctrine stands opposed, on the simplest or schoolboy level of thought, to the doctrine of special creation. We insert the qualification, not in order to suggest that the controversy is trivial, but merely lest we should seem to think it final and complete. It is a controversy essential to the truth, but it is not all. Our ancestors believed that mankind and the other forms of life, animal and vegetable, had been specially created by Deity, somewhat after the fashion described in the Book of Genesis. The Biblical account of the Deluge also consorted with this idea; and strange remnants of forms of life now extinct could thus be labelled antediluvian. The evidence of geology, with its records of strata and their characteristic fossils, required explanation; and the geologists were apparently equal to the task.

They said that other forms of life than any now known had existed, but great cataclysms of Nature had terminated them, perhaps leaving records of one kind or another behind; and that, in the new era which succeeded, new forms of life had been specially created, and so on, many times. To all this, we of to-day oppose a doctrine of organic evolution which says that no living form, extant or extinct, was specially created, but that all existing forms are evolved from forms in the past, and that the earliest of all were evolved from what we call lifeless matter; so that, in the "fire-mist" or nebula whence our planet arose, the eye of scientific faith can perceive the promise and the potency of all terrestrial life.

Remembering that we have not yet plumbed the depths, and that very few even recognised champions either of religion or of science ever do, we may realise why the controversy between this and the older view shook the world to its base, and why, after its conclusion, we live to-day in a new world of thought. The controversy involves the origin of man, and his kinship

with the lower animals. Darwin avoided this aspect of the question in his thunderbolt of 1859, but there were plenty to see that it was involved. Elsewhere in this work the evidence has been outlined which points to the kinship of man with the anthropoid or manlike apes, and to his common descent. No one could assent to the doctrine of organic evolution in general, and leave out man. The utmost possible, in the way of a distinction, was made by Dr. Alfred Russel Wallace, who argued that the spirit of man could trace no genesis from lower forms, and must be a product of special creation, though the animal origin of his body is beyond doubt.

The Battle of Thought in which there Could Be No Compromise

But even so, and even though man be left out of the question, the doctrine of organic evolution was clearly incompatible with the assertions of certain ancient literature, the verbal inspiration of which was generally believed in. The question whether or not organic evolution had happened, which is a scientific question, and which no one would dream of treating otherwise to-day, thus came to be, fifty years ago, a question of religion *versus* science. Religion was taken to make one assertion, by which it stood or fell, and science specifically denied it.

Religion declared definitely that man had been created perfect and had fallen; while science declared that man had risen from an animal stock; so that, after Darwin wrote his great book on the "Descent of Man," Professor Henry Drummond wrote a volume called the "Ascent of Man," which caused him to be accused of heresy. On the literal, practical, obvious, schoolboy plane, there could be no compromise. The disputants, with very rare exceptions, wanted no compromise; and the controversy, in the hands of most of them, and in the eyes of the general public, came to be a veritable Armageddon, with God and religion at stake against atheism and irreligion.

Organic Evolution that Shows Man to Have Risen and Not Fallen

To this view of it the fighters lent colour, by misunderstandings and misrepresentations, which we can now begin to see aright, if we will. The champions of religion fought hard and bitterly, declaring that religion was at stake, as if any kind of truth could ever compromise or do anything but strengthen any other truth. If organic evolution has happened, man has not fallen, but risen, and the Creation story in Genesis is not a statement of what actually happened. Certainly, there were serious and inevitable changes to make in the accepted belief. But the religious party went further, and declared that to accept evolution was to deny God; that evolution is materialism, excludes immortality, makes chance the master of all things, and right, wrong, and duty mere meaningless words.

Of course, there were exceptions on both sides, but on the whole there was little to choose between them, if we put aside the few really great men. For the scientific party was just as violent and extreme. The champions of orthodoxy should not have been intellectually bullied into arguing that evolution denied God, but certainly the scientific party did their best to create that impression. What we really mean by God, and what we really mean by creation—these are questions which are not asked by schoolboys, and they were not asked by the rank and file in this controversy. The evolutionists erected their word into an idol and then bowed down before it. They declared it to mean chance, with such laws as chance has, but without purpose; and they took evolution to be a cause, instead of the mode of working of a cause.

The Threefold Advantages of the Evolutionist To-day

Their opponents, eagerly fighting for the Fall of Man and the literal accuracy of the Book of Genesis, could not afford to yield anything, or they might well have accepted evolution as the statement of a *process*—which is all that it was and is—and might then have pointed out that the cause and the force manifested in the evolutionary process had still to be named and cannot be less than Divine.

We come to this question now, more than half a century after Darwin published the "Origin of Species," which started the controversy; and we are able to criticise our predecessors, because we have great advantages—advantages so great that it is our own fault if we cannot survey the matter to-day, and pierce below the thin, smooth ice upon which most minds skate, till we realise the fathomless depths beneath. Our advantages are at least threefold.

In the first place, the controversy, on its plane, has been settled once and for all, before our time. Every sane and sincere person who has looked and thought has seen that organic evolution has happened. If that fact involves the rejection of certain things formerly believed, or if, at least, it involves their rejection as literally true,

then rejected they must be, "and there's an end on't." We may regret, but we have no choice. The battle being ended, and its passions cooled, and we the possessors of the ground that the winners won, we may quietly examine it. And to this business all parties now contribute, *for, once evolution has been accepted, its real meaning becomes the concern of religion as much as of science.*

Secondly, the few deep voices on the religious side have been added to as the years have passed; and while the shallow ones are lost in the echoes of the years, these remain, and teach us that perhaps religion was at fault in lacking faith, and in having too petty an idea of God. They point out, what indeed Darwin himself pointed out, in the final sentence of the "Origin of Species," that the theory of evolution does not dispose of God, but glorifies Him by attributing to Him a grandeur and scope of method compared with which "special creation" is like the caprice of a child. Further, the professed representatives of religion are joined by those of philosophy, which occupies, so to say, a middle position between science and religion. The philosophers, deep and trained thinkers, who are always necessary to correct and amplify the conclusions of men of science as to what they find, point out that the evolutionary process is only what we see on the visible side of things, and that things are but the "living garment of God." They have lately been reinforced by a great new thinker whose views we must look at.

Meanwhile let us note the third of our advantages to-day. It is that men of science have studied and criticised and modified the evolutionary theory to great profit, both in the way of what they now assert and of what they no longer assert. We must remember that, at first, people like Huxley had to fight for the smallest acknowledgment at all of what science found. We call Huxley polemical and arrogant to-day, but we forget what measureless ignorance and arrogance and misrepresentation he had to fight against. May the next great new truth find another such champion! Born in our age, Huxley would have no occasion to fight as he did; the controversy is over, the religious world has accepted the idea of evolution, and now men of science need claim no more for it than they are assured of, and may criticise and make admissions without the certainty that those admissions will be misrepresented and used against the theory as a whole. The consequence is that the theory, as it may justly be stated by science to-day, is in some ways much more cautious and limited than the older statements of it.

M. HENRI BERGSON, THE PHILOSOPHER OF CREATIVE EVOLUTION

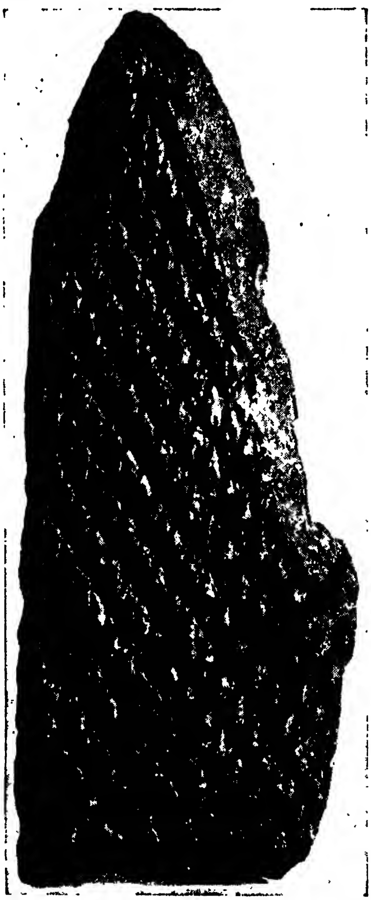
From a photograph by Gerschel, Paris.

This is where Bergson helps us. Since Herbert Spencer himself, to whom he is greatly indebted, Bergson is the first philosopher of high rank to appreciate the importance of biology. Plenty of philosophers and theologians have pronounced upon the problems of life, in the interval, but they have not studied them first. Bergson has done better. He has devoted many years to the systematic study of biology, not stopping with Spencer and Darwin and the other pioneers, but continuing with the work of their successors, and acquainting himself with all the new laboratory work, much of which dates from the last few years. No other professed philosopher of the present day has any such acquaintance with biology, for none since Spencer has realised that, before we can

pronounce upon the problem of life and its meaning, we must first acquaint ourselves with its facts—nay, not merely with the facts already known, but with countless more. Bergson occupies the middle position of the philosopher, and also the advantageous position of the man of to-day. The fighting and bad temper and over-statement of the past do not rankle in his mind, and he is not concerned to see science triumph over religion, or religion over science.

Creation *or* evolution was our simple alternative. Bergson's greatest work, the fruit of his biological study and his philosophic thought, is called "Creative Evolution." Where is our antithesis now?

The book is long and difficult. Few will read it easily yet; most will complain, as men complained of the "Origin of Species," that it was hard and obscure reading, though now we find it easy and clear. But the modern writer on biology, who strives to introduce, with absolutely impartial and scientific temper, the problem of organic evolution as it really exists and is understood to-day, neglects a duty if he does not take cognisance of this great book, which quite clearly takes us a step beyond the nineteenth century and its controversies, and builds something higher upon its solid contributions to knowledge.



FOSSILISED PLANTS—PART OF THE STEM OF A GIGANTIC CLUB-MOSS

Bergson recognises the fact of organic evolution, studies its processes, and asks what it means. To begin with, he sees that Life is different in its trend from the rest of the universe; for while the evolution of other things is always in the line of least resistance, and always resembles a running-down, as the physicists express by their doctrine of the dissipation of energy, life takes the line of most resistance, life climbs while matter descends. In other words, it constructs and creates. Behind the mechanical forces of the world there is life, which uses them for its expression, but which can never be expressed, or explained away in terms of them. The mechanical theory of Darwin, which explains the origin of species by the process of "natural selection" or the "survival of the fittest," does not escape Bergson's philosophic criticism. We shall see in due course how it stands in the face of scientific criticism, which is our own affair. Meanwhile we have to observe that, philosophically, the evolution of life cannot be adequately stated in terms of any mechanical process.

Unlike most men of science, to say nothing of amateur commentators, Bergson really understands what the Darwinian theory of evolution is, as we see from his words: "The Darwinian idea of adaptation by automatic elimination of the unadapted is a simple and clear idea." This admirable statement, in which the word "unadapted" expresses the theory exactly, neither more nor less, expresses also the fact that the theory *only tells us why the unadapted disappear*, but *does not tell us how the adapted appear*—which is the *crux* of the question.

But, being a philosopher, Bergson is bound to look closely at the meanings of words, and he is not content to take "adaptation" so easily for granted. When we speak of the adapted or the "fittest," we are using a convenient and illuminating metaphor. If we pour water into a glass, it adapts itself. to, or fits. or repeats the form of the glass. That is mechanical adjustment. Similarly, a key may be made to fit and turn a lock: and thus, in metaphor, we may think of any living species as a key which turns, because it fits, the lock of its environment—to use an illustration employed by the present writer some years ago. All this is useful so far, and especially useful against the misinterpretation which confounds the survival of the fittest with the survival of the

best—as we shall see when we come to study Darwinism. But Bergson points out, to those who would reduce evolution to a mechanical problem, like a locksmith's, that we must not be "fooled by a metaphor."

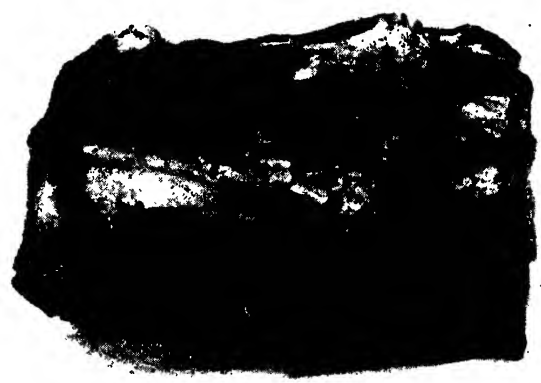
Life is not poured into a mould, made by the circumstances. "It will have to make the best of these circumstances, neutralise their inconveniences, and utilise their advantages—in short, respond to outer actions by building up a machine which has no resemblance to them. Such adapting is not *repeating*, but *replying*—an entirely different thing." Adaptation, the great fact and consequence of evolution, which any theory of it must explain, is not the "impress of circumstances, passively received by an indifferent matter," but is "an effort of the organism to build up a machine capable of turning external circumstances to the best possible account."

This means that evolution is creative. It supports Bergson's idea of a "vital impetus," or "*elan vital*," to use his own term, which various translators have called the "momentum," the "thrust," the "impetus," the "go" of life. This, as we have seen, opposes and transcends the mechanical movement of matter, and cannot be comprised within the terms of mechanism. It is transmitted from generation to generation, and expresses itself in all the forms of life, some along roads which lead no further, but one, which we call human and intelligent, along an open road. Here is creation, displayed in the form of evolution; and the materialism of the nineteenth century is dispelled, and replaced by a deeper view, which sees that creation is not "special" because it is universal and eternal.

Having thus considered the larger aspects of our great subject, aspects which do not concern the ordinary levels of science, we may pass on to our own proper topic, simpler, if less momentous. We have asserted that the fact of organic evolution is beyond cavil and is now disputed by none. We must look at the main lines of evidence for this confident and dogmatic assertion, which science is entitled to make.

It consorts with everything else we know—the history of rocks, stars, atoms. That is a statement which no one could make half a century ago, when the facts of universal evolution were unknown.

Most serious for Darwin, and for all evolutionists until very recent times, was the geological objection to which, in his chapter, he gives full weight. It is that the records of the rocks do not afford intermediate varieties between species, such as we should expect, if they had been evolved from one another by slow and insensible degrees. If that had been the process, then the rocks should show us some traces, at least, of transitional forms corresponding to intermediate stages between this and that species, now extant. Darwin definitely argued that evolution is a gradual process, that Nature does nothing by sudden jumps, and that species have arisen by the steady accumulation of minute differences. On that view, the "imperfection of the geological record" was a great difficulty. But it is not so difficult for us. Professor Hugo de Vries of Amsterdam, and Professor William Bateson of Cambridge and the Royal Institution, have shown us how new forms may arise suddenly, the old adage about Nature's dislike of jumps notwithstanding.



FOSSILISED ANIMALS—FLIES PRESERVED IN AMBER COUNTLESS YEARS AGO

In our day the study of the development of the individual has greatly strengthened the case for evolution. This study, in the case of the higher animals, is called embryology, being so largely concerned with the examination of their early or embryonic stages. As we have already seen, the facts of development, when we compare them in widely various species, are unintelligible unless we try to interpret them on the assumption that evolution has happened.

If, however, we apply the law of recapitulation to the problem, we see how the strange and often apparently absurd details of individual development find an explanation. The young creature is climbing its own ancestral tree. If we assume, for instance, a fish-like form in the ancestry of man, many facts of the human embryo become intelligible at once which otherwise look as if Nature had gone mad.

The Far-Back Relation of Man to the Anthropoid Apes

So also the study of the anthropoid apes and of man reveals a similarity at certain early stages—including, for instance, in both cases, the formation of a tail which afterwards practically disappears—so striking and detailed that no one can resist drawing the only possible inference.

In our own day, also, as regards the tremendous case of man, we have further evidence, such as the discovery of the "ape-man," the remarkable similarity in the blood-reaction of man and the anthropoid apes, and their similar susceptibility to certain diseases.

A great and general difficulty has to be named, which at one time seemed insuperable, or nearly so. Indeed, Huxley always maintained that he could not regard the theory of organic evolution as proved so long as species remained incapable of mating with each other to form new species. There are many cases where different species can mate, producing such offspring as, for instance, the mule. These products of two species we call hybrids, and it appeared to be a constant rule that hybrids are sterile. If that were so, evidently the possibilities of the formation of new species are seriously limited, but the sterility of hybrids seemed to be Nature's rule. It must be remembered that experimental breeding, either of animals or plants, by men of science, and for the purposes of knowledge, was a very rare affair until the present century.

Barriers that Disappear in the Light of New Knowledge

Biologists had to go by the opinions of breeders, such as Darwin himself frequently quotes. He, however, performed breeding experiments, and Mendel did so too, though no one knew about it; and later De Vries and Bateson and many others have taken to experimental breeding on a large scale, most notably in the United States of America.

The study of hybridisation, which used to be looked upon as a curiosity, and of no general moment, has been placed on an entirely new level by the work of Mendel and his followers; and one of the most important of the results they have obtained is that hybrids are by no means necessarily sterile, and, even when they are, the sterility may only be due to accidental circumstances of structure, and not to any inherent disability of the hybrid to reproduce itself. Indeed, many hybrid forms can be bred and found to breed true, so that new races can be created.

What this means for the theory of evolution is our only present concern, but it is a great one. It means that the supposed barriers between species, like the other barriers which men erect in Nature, disappear on further knowledge. Our idea of a species as an immutable thing, self-contained and separate for ever, cannot be maintained when we see how species are really constituted, when we learn the results of hybridisation, and when we begin to think of all individuals as living mosaics, from or to which certain constituents may be taken or added, or substitutions made, in any degree, until one species becomes another.

The Fact of Organic Evolution that is Positively Known

In any particular case this may not be feasible, but in many it is, and the lesson is plain. Huxley's notable and long-maintained criticism is thus met; and we are able to look at the theory of evolution with ideas of what constitutes a species, and of the relations between species, which make it seem far easier to understand.

For many future chapters of this section, and for many decades to come, we shall be concerned with the factors of evolution, and with weighing the factors which we must admit, and seeking to interpret the multiform problem before us. Let us be as clear as words can make us: that science positively knows the fact of organic evolution, that to doubt it is sheer ignorance, and that it is a fact worthy to be known by all thoughtful people. And then let us be equally clear that science cannot yet explain the fact, that we cannot even attach anything like the same weight to certain explanations as we used to suppose, and must do much hard work, above all by means of experimental breeding of animals and plants, before we can offer an explanation to complement our description. Similarly, in another branch of science, the authorities teach us that gravitation is a universal fact, which they rightly assert with absolute dogmatism, but if they are asked to explain

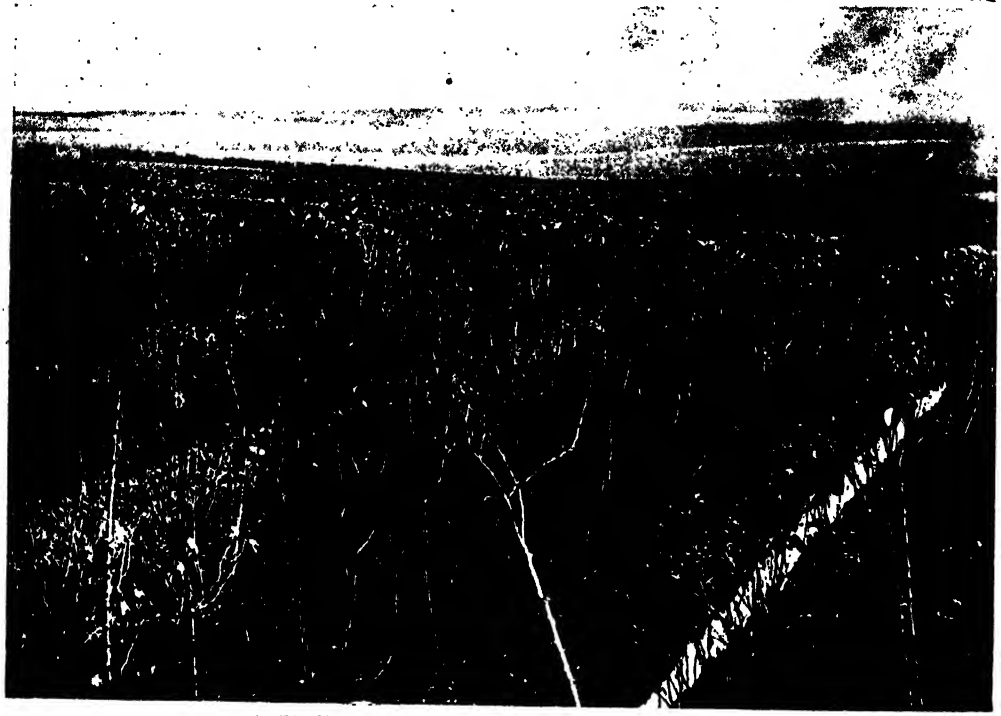
gravitation they can only say they do not know. We know much more towards the explanation of organic evolution than astronomers know of gravitation, but we have the greater part yet to learn.

One serious and urgent question must here be raised in conclusion. Organic evolution is a fact. The modern attitude towards the particular theory of its explanation called Darwinism is not the same as Huxley's, and we see that there is yet more to learn, but the fact stands, and will stand. No future discovery of science will ever restore "special creation" to its old place. This being so, are we any longer entitled to usher children and young people into the world of modern thought by teaching them the doctrine of "special creation," or has the time come when we ougth to teach what we believe? The man of science can give only one answer to this question; and the practical moralist has plenty of facts already with which to guide his decision. Our young people will certainly grow up to learn that organic evolution, including that of man, is a recognised and unquestioned truth. It cannot be kept from them, nor they from it. If we do not teach them, others will. A recent book on the study of Nature, written for and used in the most illustrious school in this country, carefully speaks throughout as if evolution had not occurred. The only result of such a cruel and cowardly policy is that our young people learn the facts for themselves during the critical and deeply impressionable age of adolescence, and learn them from sources which are less concerned with presenting the facts fairly than with using them as weapons against religion. The "Origin of Species" would once have been publicly burnt by the common hangman; there are Churches which would burn it to-day if they could, but it can be purchased anywhere for fourpence-halfpenny. That noble book can morally harm no one, though it has distressed many. But our youth are as likely to learn the facts from violently materialistic books, belonging to an era of thought now obsolete, such as Haeckel's "Riddle of the Universe," and works of that kind. The powers in the Church and the educational world, right up to the stage of university education, who now ignore their duty in this matter, or who positively base religion and duty and morality upon doctrines which are incompatible with evolution, are responsible for the grave consequences.

JEAN BAPTISTE LAMARCK, THE GREAT FRENCH NATURALIST

This doctrine is true, it is important, and it is intelligible—perfectly so to any boy or girl of twelve or fourteen. If those three assertions be granted, what possible excuse can there be for not merely ignoring it, but for teaching the views which no sane and thoughtful adult now believes, or ever will believe again? Something must be taught, as, for instance, regarding the origin of man. The alternative is between teaching the truth, and teaching what is not the truth, and what we know—and will in due course be found to have known—not to be the truth. The child whose confidence has been thus abused will grow up and find us out. In some instances suddenly and consciously, and perhaps with measureless distress of soul, in other instances gradually and only half consciously, he will cease to believe what he has been taught by the united voices of all the adults whom he should be able to trust. He will throw away the dross, but with it he will also throw away some gold.

Yet may it not be that the necessary teaching of our young people is easier if we look at organic evolution in the light of the foregoing pages, and carefully distinguish between the indisputable, descriptive fact, the problem of its explanation, and the grandeur of its meaning? It may be hoped that the time is nearer, in consequence of these arguments, when those responsible will see the doctrine of organic evolution as it is, not as violent controversialists on both sides misrepresented it a generation ago; and then we may begin to discover that morality can be better based upon the "solid ground of Nature," even though the waters to dive through be black and deep, than upon the thin ice to which the frail of faith have trusted hitherto.



A FARM FERTILISED BY SEWAGE FROM A TOWN

THE VALUE OF MANURE—FORCING-BEDS FOR MUSHROOMS IN A FRENCH GARDEN AT BURHILL

THE VALUE OF MANURES

The Means by which the Food in the Storehouse of the Soil is Replenished and Its Value Enhanced

ENRICHING THE SURFACE OF THE

We have already gained some idea of the marvellous and complex capacities of the soil. We have seen how it is the great source of life for the world, and we have seen also that in the course of time this life-giving power may become exhausted. It was this which made the preparation of the soil, which occupies so much of the attention of the farmer, a necessity, and which brought the processes of cultivation to their present state of perfection.

We realise now that since all life, both plant and animal, depends upon the various processes which we have described as taking place in the laboratory of the soil, it is quite obvious that as the result of this constant and immense drain upon its resources there must sooner or later come a time when the supply will fail. Put in another way, one might say that, owing to the immense amount of exports which the soil sends out to the communities of plants and animals, there must of necessity be a process by which these are replaced by a corresponding amount of imports. In fact, if we wish to render a soil more and more prolific, and to make it richer and richer, or, as we say, to make it more fertile, we have to insure that the imports must be in excess of the exports. This constant replenishment of the substances which are withdrawn from the soil for purposes of plant nutrition is accomplished by the process which is usually spoken of as "manuring," and upon this replenishment continued fertility depends.

Fertility, in the first instance, as we have by now learned, depends upon the physical properties of the soil, aided by the bacterial processes which go on within it, and, lastly, by the actual composition of the soil in question. All these properties, upon which fertility depends, although differing very widely in themselves, have considerable influence upon each other; and so we find that it is not sufficient for a ... .. show excellent chemical characters of composition. It must also have certain physical or mechanical qualities which will enable the bacteria to carry on their part with success, and which will also allow air and water to act without interference.

Of these properties we have already discussed the part played by bacteria, by air, and by water. There remains for our attention that aspect of the soil which is concerned with its chemical nature, and, as a matter of fact, from the point of view of the farmer; this last is by far the most important, for the simple reason that it is the aspect which is most directly under his control. This replenishing of the soil, or manuring of the soil, constitutes the study known as "Agricultural Chemistry."

It is interesting and instructive to note in a few words what has been the progress and development of this study, which is really a very modern science. The ancient idea of the composition of matter was that of Aristotle, who divided the elements into those of earth, air, fire, and water; and that primitive conception was held in one form or another until chemistry took its birth as a science. Then, in the early part of the seventeenth century, came Van Helmont's theory which laid down that all the products of plants were capable of being produced from water. In 1661, Sir Kenelm Digby propounded the view that the growth of plants was dependent upon a balsam in the air.

Some mention of Jethro Tull's theory must be made, because it certainly contained a truth, if not all the truth. This theory stated that the fertility of the soil depended entirely upon its pulverisation into minute particles. These particles actually themselves constituted the food of plants. This theory is interesting, because it emphasises

one important aspect of cultivation, namely, the breaking up of the soil, which, it was recognised, took place in Nature to a certain extent, as the result of the operation of natural forces, quite apart from the farmer.

The first real progress in the matter was not made until late in the eighteenth century, when the Swiss naturalist Charles Bonnet made his [redacted]ery of the real [redacted]ch plants require. [redacted]aves were soaked [redacted]gas were seen to [redacted]ce. These bubbles [redacted]erwards identified by Priestley as oxygen; and it was established that this oxygen from the plants was only given up by them under the influence of sunlight. Finally, it was shown by Jean Senebier that the source of this gas which Bonnet had noticed coming from the plants, and Priestley had shown to be oxygen, was the carbonic acid gas in the air which the plant had absorbed and decomposed, keeping the carbon for itself.

The Discovery of the Relation between Chemistry and Plant Growth

After this, many earnest students devoted their attention to plant chemistry. The great discoveries of recent years on the subject are practically all to be traced to a report made in 1840 to the British Association by Liebig, who maintained that all scientific agriculture must be based upon an exact knowledge of the nutrition of plants, and of the influence of the soils and the actions of manure upon them, and that this knowledge could only be obtained from chemistry. It was Liebig who first insisted upon the importance of the minerals in connection with plant life. Indeed, his great claim upon the gratitude of those who followed him was that he attracted attention to this line of investigation.

Shortly after this there began the epoch of agricultural research in which Germany led the way, thanks to the munificent grants of the Government. Experimental stations were established, and to-day there are some eighty of these in Germany and about fifty in the United States. Our own famous Rothamsted station, which dates from 1843, comes under this category. It is associated with the names of two great English chemists—namely, Sir John Lawes and Sir J. H. Gilbert. To the work done on this station we owe to a great extent our knowledge of the function of nitrogen and its relations to plant life, the results of which we have already spoken of in connection with the fixation of free nitrogen from the atmosphere and the process of nitrification.

Coming now to the precise nature and function of manures, we may note that the word itself means "to work with the hands," which evidently has reference to the fact that the tilling of the soil by the hand was a great aid to fertility. But the process of manuring now has a much wider meaning than this; and we may define manure as any substance which, when applied to the soil, contributes to its fertility.

Soluble Elements in Manures that Feed Plant Life and Break Up the Soil

Our previous studies have shown us that the substances which plants especially require, and which are most apt to be absent or insufficient, are nitrogen, phosphorus, and potassium. Manure, therefore, to be of any service, must contain these three ingredients, and its commercial value will depend upon that fact. It must also be remembered, however, that the mere presence of certain constituents in the soil is not in itself a guarantee of fertility, because they must be easily soluble in order to be used, and the soil itself must be of the proper mechanical character, as well as possessed of the requisite bacteria.

Manures are of different kinds. Some add directly to the fertility of the soil by giving it the necessary substances for plant food. Others act indirectly by improving its mechanical or chemical properties. Some manures are *general* in their action, assisting fertility in every way. Others are *special*, contributing certain definite constituents. Looked at in another way, certain manures are natural—that is, derived from natural sources—while others are artificial, being manufactured for special needs. And all of these may be again regarded from a different aspect as to whether they are animal, vegetable, or mineral.

Is the Soil Becoming Poorer in Nitrogen Every Year, Notwithstanding Scientific Manuring?

The easiest method of classification of manure is that suggested by Professor C. M. Aikman, a great authority on this subject. He divides manures into three groups:

1. Those which act both directly and indirectly, such as farm manure and sewage
2. Those which have only a direct action, such as guano, bones, nitrate of soda, sulphate of ammonia, dried blood, superphosphates, mineral phosphates, horns and hoofs, shoddy, and so on.
3. Those which have only an indirect value, such as lime and salt.

Nitrogen, phosphorus, and potassium are the only three ingredients which it is

usually considered advisable to apply as artificial manures, and nitrogen has already been considered in some detail as regards its source in Nature. We may next note, therefore, in what way this element is supplied artificially. It is added to the soil in the form of nitrogenous manures, especially nitrate of soda and sulphate of ammonia.

Over two and a quarter million tons of nitrate of soda are exported annually from Chili for artificial manures for use in other parts of the world; a considerable proportion of this finds its way into Great Britain. On the other hand, sulphate of ammonia, the total production of which in Europe may be stated roughly at 200,000 tons, is exported from this country, where about half of the total is produced. Other sources of nitrogenous manure are Peruvian guano, the beds of which are becoming nearly exhausted; bones; and a number of by-products, such as fish-guano, dried blood, horns, hoofs, soot, hair, and so forth. A further considerable source is that from oil-cakes and oil-seeds, which, besides nitrogen, contain also phosphoric acid and potash.

The question may be very well asked: Is nitrogen, thus artificially supplied, capable of taking the place of that which is lost from the soil? Sir John Lawes is of opinion that this loss is not so made up, and he estimates that there is a loss of nitrogen varying from 15 lb. to 20 lb. per acre per annum in agricultural land. Others, however, estimate the loss at considerably less.

OXYGEN BUBBLES FORMING ON LEAVES IN WATER

Next we may consider the question of the artificial supply of phosphorus, the second of the important plant foodstuffs which can be supplied artificially. This is a much simpler matter than the question of nitrogen, which has occupied so much of our consideration up to this point; for the plant needs less phosphorus than nitrogen.

Phosphorus occurs in the soil in comparatively few combinations; and there is really but a very limited amount of it. reckoned in the form of phosphoric acid. As we saw in our earlier chapter, it is derived from various rocks. In fertile soils phosphoric acid is never present in more than one-fifth of one per cent. In most soils the amount is considerably less, whilst in the well-known Russian black earth it may reach the amount of 6 per cent. In the soil it occurs in an insoluble condition, principally in the form of phosphates of lime, iron, and alumina. In animal bodies it forms slightly more than 2 per cent., and in plants the amount of phosphates in the ash may be put from 5 to 16 per cent.; and these sources, of course, contribute to the supply of phosphoric acid to the soil.

We may therefore summarise the position of phosphoric acid in this matter thus: its natural sources are first of all mineral, from rocks and coprolites (rounded lumps of phosphate of lime); the guano deposits of South America; the result of the decay of dead plants; and a similar source from animal bodies. Its loss from the soil is due to only one natural process—namely, drainage—but the artificial losses are more numerous.

When crops are removed from the locality of their growth, a large amount of phosphoric acid is taken with them. It was estimated that in this way the total loss for the crops in France in one year was about 298,200 tons, while only 157,200 tons were returned in the form of farm manure. The deficit would have to be made good by applying artificial phosphatic manure. There is also a loss in the form of milk, no less than 11 or 12 lb. per cow per annum going in this way; while the farmyard manure and methods of sewage may also draw away a certain amount.

This total loss of an important element must be made good from the natural sources of mineral phosphates, as well as the application of various forms of manure, together with bones and guano. In recent years the substance known as "basic slag" has also been largely used to supply this loss.

It is a by-product in the manufacture of steel, and is rich in phosphates. Other sources of supply are the various food supplies which we import, and from these varied sources the natural and artificial loss of phosphoric acid is made good.

The third constituent which we stated to be of importance in this connection was potassium, for which we may perhaps use the common name of potash, which is the only part of the ash of the plant, except phosphorus, which it is found necessary to supply artificially. But since potash is found in the soil in much greater quantities than phosphoric acid, it follows that its artificial supply is less important. Besides, although it is removed to a certain extent in agricultural processes, it is also returned very largely in farmyard manure; for example, ordinary straw contains a larger proportion of potash than it does of phosphoric acid, and it is for this reason that straw forms so important an ingredient of the manure of the farm.

A COMPARISON OF VARIOUS METHODS OF FERTILISING TREATMENT

This picture shows the results obtained with clover grown in Westland mica silts for obtaining the values of manures as compared with No. 1, to which no manure was added; in 2, stable manure was added; in 3, superphosphate; in 4, lime; in 5, carbonate of lime, and in 6, basic slag.

Potash occurs in the soil principally in the form of soluble silicate of potash derived from the rocks. It is the most abundant ingredient of the ash of plants, forming about half of the total. In plants themselves this is found in large quantities in cereals and in the young twigs and new leaves of green plants. Animal tissues and blood contain it in abundance. The sources of its loss are principally found in the removal by crops and milk, the root-crops especially being those concerned. Since the soil retains potash compounds with greater tenacity than phosphoric acid, the loss of the former by drainage is not so great. The manures used to restore this loss are those which have as their chief source the Stassfurt deposits, in Germany. The commercial form of the manure is known as the "muriate."

Now we may turn our attention from the chemical constituents required in artificial manures to the actual forms of manure which are used to supply these elements, their modes of application, and their values with regard to special crops.* Doubtless the oldest manure used in agriculture is that known as "farmyard manure," and it is still the most popular. Its popularity, moreover, has been earned as the result of practical experience; and it remains to-day, considered from every point of view, the most valuable of all natural manures.

It is a difficult matter to state precisely the reason—or, rather, the reasons—for this value, because the action of this fertiliser is not a single one, but is very varied. To understand it we must endeavour to appreciate its varying qualities and properties. The natural idea, of course, would be to suppose that the value of farmyard manure consists in the richness and amount of the foodstuffs contained in it. This is, as a matter of fact, the idea of the uneducated agriculturist. It may be stated at once that its value from this point of view has been and is considerably over-estimated. The way to test the question is to ascertain what quantity and proportion of the three essential constituents of good manure are contained in it.

Estimated by this standard, we find that farmyard manure contains comparatively little nitrogen, phosphoric acid, and potash, and, moreover, what it does contain of these substances is not of great value for plant use, because some of it is insoluble. Then, as regards the relative proportion of these three substances, they are not found to be present in farmyard manure in the

proportion required by the plants; and experiments of Rothamsted have shown that farmyard manure restores mineral ingredients, but is inadequate for the purpose of supplying nitrogen. The conclusion one is driven to is that the real value of farmyard manure must be in its indirect action rather than its direct influence.

In the first place, of course, it adds much organic matter to the soil to which it is applied. It also helps the soil in attracting moisture, a point of great importance in connection with the sowing of seed. Further, it assists in the opening up of the soil to the action of the air and water, and these help the soil to become more friable. And, lastly, the warmth of the soil itself is increased by the putrefaction process which goes on in the manure, and it sets free a large amount of carbonic acid gas, the importance of which we have already studied.

These mechanical and indirect properties of farmyard manure are most obvious when it is fresh, so that it is to soils that require these properties that it should be applied in this form. The well-rotted manure would in a similar manner be most valuable on light, sandy soils, or those well cultivated. The application of it has probably been excessive in the past; and modern opinion seems to favour the view that there is more advantage to be gained in more frequent applications of smaller amounts than a very heavy dressing at one time. Even then the extreme gain in the first year does not cover the cost of application, but to balance this the effects go on for a number of seasons.

Nowadays, largely as the result of practical experiments, it is no longer regarded as the best policy to manure the *soil*; attention is rather directed to manuring the *crop*. Farmyard manure, therefore, owes its value to the many different ways in which it acts, either directly or indirectly, rather than to its position as a definite fertiliser.

We may next note another of the more important natural manure, namely guano. Not that it is a manure very extensively used to-day; indeed, the contrary is the case. Its interest is to a large extent historical, because, although bones were used long before guano, guano was the first of the imported manures to be used in this country to any great extent. From its introduction about the middle of the nineteenth century may be dated the modern system of what is termed *intensive* cultivation.

Until guano came, farmyard manure was practically the only fertiliser used; and the result was that the farmer was restricted to certain rotations of crops in order to get the best result from his land. It was impossible for him to *manure the crop*; he had to *manure the land*. But, following the introduction of guano, he soon discovered that by the application of a few hundredweights per acre almost barren portions of land could be made to yield an average result, and his general returns were much greater. He further found that his crops started better, and that their growth could be quickened. No wonder, therefore, that guano for the time eclipsed the use of farmyard manure and bones. It was to it undoubtedly that we owe the favour with which special fertilisers are now regarded.

The value of guano consists in the large amount of nitrogen and phosphates that enters into its composition. Some kinds are composed almost entirely of phosphates, but usually all three of the important elements are present. It is derived from the excreta of sea-birds, especially pelicans, gulls, and penguins, together with the bony remains of sea-animals and others. Its principal source of supply was the deposits of Peru, where immense masses of guano were deposited and covered over with sand, which probably, to some extent, prevented the loss of nitrogen. These deposits are now almost exhausted, but many other places in the world have also supplied it.

The quantity of guano to be used, as, indeed, of any special fertiliser, depends

RESULTS OF ARTIFICIAL MANURES ON AN EXPERIMENTAL FARM

The relative sizes of these heaps of turnips show the results obtained from applying different manures to equal sized plots. Manures were added to the plots as follow: (1) superphosphate, 4 cwt.; (2) superphosphate, 4 cwt., and sulphate, 1 cwt.; (3) no manure; (4) guano, 4 cwt., and sulphate of ammonia, 1 cwt.; (5) bone-dust, 4 cwt., and sulphate of ammonia, 1 cwt.; (6) basic slag, 4 cwt., and sulphate of ammonia, 1 cwt.

upon the kind of soil, the crop to be raised, and whether other manures are to be added also. The average application may be said to be from 1 to 4 cwt. per acre, though Scottish farmers quite commonly use 6 to 8 cwt. in the case of turnips. Sir J. B. Lawes and Sir James Caird estimated that 2 cwt. per acre increased the wheat crop by eight or nine bushels of grain and one-fourth of straw. With reference to turnips, for which it is specially useful, the more phosphatic guanos are especially valuable, the best results being obtained from the application of the guano at two periods—once before the seedtime, and again between the drills when the plants are up.

The most important artificial fertiliser in modern use, however, is nitrate of soda, or Chili saltpetre. This has now largely taken the place of guano; and there is no question that it is one of the most economical and profitable sources of nitrogen for the plant. It is imported into this country in very large quantities, not only, however, for fertilising purposes, but also in the manufacture of nitric and sulphuric acids, as well as gunpowder.

Enormous and Invaluable Fertilising Deposits that are Difficult to Account For

The famous nitrate deposits of South America, from which we draw our supplies, were one of the causes of quarrel between the States of Chili and Peru. These deposits are found in barren, sandy deserts, where there is practically an entire absence of rainfall. The districts are at an altitude of 3000 to 4000 feet above sea-level, and many of them eighty or ninety miles from the coast. It is impossible to discuss here all the theories to account for these deposits. One of the most probable, however, is that they are due to the decay in former times of huge quantities of seaweed driven there by tempests.

The amount of these deposits may be guessed at when we state that a French authority once estimated that they contain 100,000,000 tons of pure nitrate of soda.

The commercial product is composed of about 95 per cent. of pure nitrate of soda, which is equivalent to about 15½ per cent. of nitrogen, so that it is, next to sulphate of ammonia, the most concentrated nitrogen fertiliser we have; and, moreover, the nitrogen in it is in that form which we have already seen is that required for the plant use. It has also the advantage of being very soluble, so that it is readily diffused in watery solution in the earth.

All these advantages render the nitrate of soda particularly valuable as a top-dressing. Applied in this way, there is the least possible loss from drainage, and the nitrogen is conveyed to the destination where it is required—at the roots of the plant. Being carried down into the soil in a state of solution, the roots of the plant are encouraged to grow down after it; and thus it is that this manure encourages deep roots, a result which is of great value to the farmer, because deep roots enable the plant to withstand the absence of moisture for a longer time than they otherwise would be able to do, and they also bring a greater area within the reach of the plant for purposes of nutrition.

The Nitrate that Most Stimulates Growing Grain when Used as a Top-Dressing

The crops for which the nitrate of soda fertiliser is admittedly valuable are the cereals. Probably it is not of so much value to roots, except the beetroot, for the cultivation of which it is largely used in Germany. It need hardly be said that in the case of peas, beans, clover, and other leguminous plants, there is not the same necessity for its use, inasmuch as these plants, as we have previously seen, are able, by means of other processes, to obtain the nitrogen they require.

We have already hinted that the method of application of nitrate of soda should be that of a top-dressing. Its ready solubility and its immediate usefulness would indicate this. It is usually advised that it should be applied a little at a time and uniformly scattered; and it is frequently mixed with loam or salt. Finally, when using this form of fertiliser, it must always be remembered that the other important constituents not contained in it must also be supplied to the soil if they are deficient.

Phosphates that are Turned Out of Steel Sent Back to the Earth as Manures

Of other fertilisers, mention may be made next of sulphate of ammonia, the source of which is principally in the manufacture of gas, in which it is a by-product. It is also obtained from the shale-works of Scotland. Sulphate of ammonia is a whitish crystalline salt when pure, but usually brownish in the commercial article. It is very soluble in water, and is a concentrated nitrogenous manure, and hence very expensive. It is applied in only small quantities, usually from 100 to 125 lb. per acre; and this should be done sufficiently long before the crop requires it to allow of its conversion into the necessary nitrates. Its chief use is for cereals, and its best results are got when mixed with other fertilisers.

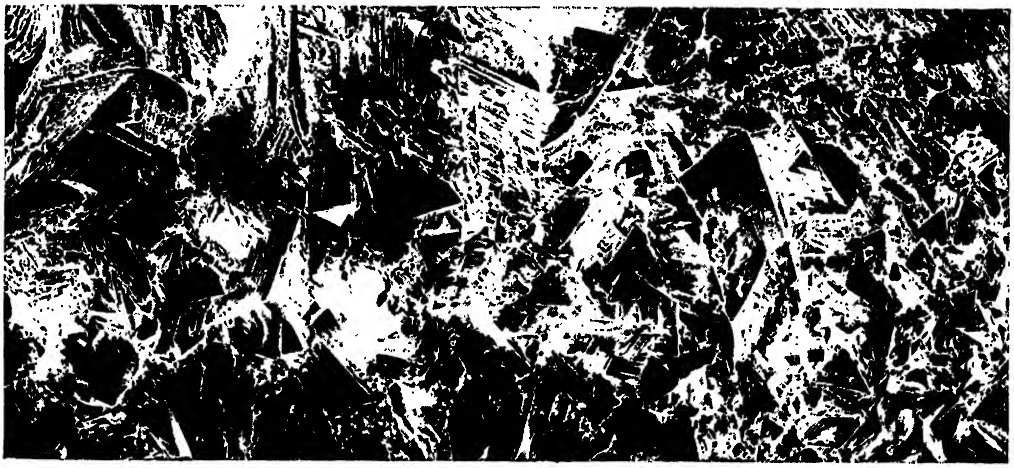
The use of bones as a fertiliser dates from

about 1774. The demand grew so quickly that a large import trade soon grew up. In their earliest application they were simply introduced whole or in large pieces, but later on were broken up by machinery. They were also allowed to ferment in water; and in 1840 Liebig discovered the value of treating them with sulphuric acid, which ultimately led to the use of superphosphate of lime. Their action as a fertiliser is slow, and is partly mechanical and partly chemical.

Coming next to the use of superphosphates, we may note that they are manufactured in three classes according to the percentage of the soluble phosphates contained. The lower class contain less than 24 to 25 per cent.; the medium class, or ordinary superphosphate, 25 to 27 per cent.; the high class up to 45 per cent. When this substance is added to the soil it is converted into an insoluble salt, upon which the roots of the plant act by means of their sap. It becomes very closely mingled with the soil particles, which is the main reason of its superiority over ordinary insoluble phosphates. It should be applied some time before it is required for assimilation, in order that it may be neutralised. The amount used is from 2 to 3 cwt. per acre in England; 6 to 8 cwt. per acre in Scotland, for turnips.

One of the most important of the modern artificial fertilisers is basic slag, a by-product in the manufacture of steel. One of the impurities in making steel from pig-iron is phosphorus. In the process of steel manufacture the phosphorus is converted ultimately into phosphate of lime, which is the fertiliser in question. It contains also, however, other salts. It is equally valuable for all soils, its greatest effects being in those which are rich in organic matter, poor in lime, or which are of a peaty character. It contains a good deal of free lime. Professor Wrightson recommends its application at from 6 to 10 cwt. per acre. It must not be used along with sulphate of ammonia, or else there will be considerable loss of ammonia itself. It can, however, be mixed with advantage with nitrate of soda and with salts of potash, a little sawdust being added to prevent this mixture running into hard cakes or balls.

Such is a brief general sketch of the more important artificial fertilisers which are in use in agricultural procedures at the present day, regarded from the point of view of the supplying to the soil of the three absolutely essential elements which it is apt to require. We need hardly say that there are a great many other forms of special manures, and to these we shall have to make reference in various subsequent chapters when dealing with the growth of plants. Here, for example, nothing has been said with regard to the manurial action of sewage, nor the use of composts, neither have we referred as yet to the group of indirect manures as represented by lime and salt. We shall be able, however, to recur to these points when we come to discuss the growth of certain crops and the action of certain fungoid diseases which affect certain plants, and again when we deal with the production of grass and pastures, as well as the growth of wheat. For the present it will suffice if we make ourselves perfectly clear as regards the essential ingredients which artificial manures may contain, and which are apt to be lost by the soil on account of its exhaustion by crops.



THE RICHEST FERTILISER THE CRYSTALS OF SULPHATE OF AMMONIA

ARABIAN CAMELS WITH THEIR OWNERS IN THE DESERT

THE BACTRIAN CAMEL OF THE DESERT REGIONS OF CENTRAL ASIA

ANIMAL HELPERS OF MAN

Man's Miracles of Mastery—The Animals He has Trained to do His Work on the Fringes of Civilisation

SHOULD MORE SPECIES BE TAMED?

In this age of electricity, steam, and fuel-oils, man remains strangely dependent for his existence upon animal life. He and the ants are the only living creatures that have pressed other living creatures into bondage. The ant makes slaves and keeps herds of "cows," and maintains a highly organised communal life. The slave-making ants become in time wholly dependent upon their servitors; man in many a land would perish were he suddenly deprived of his allies of the lower orders. Indeed, some scientists foresee a day when civilisation may be menaced by lack of animal help; the day when we shall have exhausted all the vegetable fuels, such as coal and petroleum, when we shall be driven back to reliance upon animal labour, and find the supply insufficient. From this quarter comes an earnest appeal to the present generation to "domesticate, domesticate, domesticate," and add new animals to the list of those which serve us in the production of power.

Many miracles have been achieved by the men who have attained to mastery of the wilds. Man's attitude towards the animals that he has subjugated has been wiser than his attitude towards his fellows. A Napoleon seizes upon the biggest and most powerful men in many nations, forces them into his armies to be shot dead or maimed for life, and leaves a continent bereft of its finest physical types of manhood, so that during the two or three generations following the decline in the average stature is such as to make compulsory the lowering of the minimum standard of height admitting into the armies of Europe. In his dealings with the beasts man has shown more enlightenment. He has taken the best for the sires and dams of his flocks and herds; it is the inferior that he kills. He prevents the inferior types from increasing their numbers.

He creates a new animal in the mule; he multiplies breeds of animals and birds by the hundred. He has improved upon Nature as well in regard to animal life as in regard to vegetable life. He goes into the jungle and brings home captive the lord of the animal world—the colossal elephant—and in a few months makes it his willing slave; he polices his body with benevolent bacilli. He sends the bloodthirsty cheetah to pull down the fleet-footed stag, and himself becomes, as it were, the foster parent of salmon and trout and oyster and crustacean. He makes the camel his ship in the desert, and harnesses the minutest of nature's children, the mico-organisms of the soil, to grow for himself a dish of vegetables or a posy of flowers. He has taught the otter and the cormorant to fish for him; he has lured the fowl from the jungle and made it as prolific of eggs as a beetle. The yak and the reindeer, the Bactrian camel, and the dog are his pack animals in the frozen wilds; the true llama owes him its existence. The beauty-birds, such as the peacock, have surrendered their liberty to become contented denizens of his home; the duck and the goose and the swan forget that they and the wilds ever were associated. His are the cattle upon a thousand hills, and practically every species of sheep in the world that has value for wool and flesh, and the strings from which the violinist wooes divine melody, is of man's selection and development. The same skill that has produced from the hog-maned weedy animal of the steppes the speeding racehorse or the superb animal that draws a London dray, has evolved also the comfortable domestic pig—the peasant's wealth—from the wild pig of the forest; has made the caterpillar of the silk-moth yield robes of luxury, and has caused the bee to surrender honey and wax as rent for the home that man provides. He claims the

service of the ladybird to patrol his plantations and his rose-garden; he tames the polecat into the ferret to rid him of mice and rats, a task to which he also has educated the cat and the mungoose; and he nurtures the civet to yield him perfume as if it were a flower.

To-day we are in some respects less dependent than we have ever been before upon the services of the animals which merely labour for us, yet the British Empire is run, upon its arid and Arctic fringes, by camel labour and by yak labour; and the Post Office with all its multitudinous resources, has to depend in winter, for the distribution of the mails, upon teams of dogs, a means upon which the police of our far North-West have also to rely, the highest hope of these two branches of the Imperial service being that some day the villainous, half-wild wolf-dogs of these desolate lands, which in time of hunger turn and rend and eat their masters, will be supplanted by the gentle reindeer.

Which is the most valuable of the animal legacies from the unstoried past? We may leave to another chapter the animals with which we are all most familiar, and confine ourselves here to those that keep the Empire going in its farther ramifications. Obviously the decision must lie with the camel and the reindeer. The mahout who loves his elephant would demur to this conclusion; so perhaps would natives of Africa if they had had sense enough to domesticate the noble elephant of the Dark Continent. But, taking all-round utility, and leaving out of question the matter of lovability, intelligence, and fidelity, the palm must be awarded to one of these two animals, the camel and the reindeer.


THE VICUGNA

The camel is the greater puzzle. The puzzle is not as to distribution; that has been triumphantly solved. The family exists now, in numbers, only in the desert regions of Western Asia and North Africa, but its relatives flourish in the Andes and the temperate plains of South America, in the form of alpacas, llamas, vicugnas, and guanacos. Vastly as they differ superficially, the animals are closely akin in all essentials of structure, even to the peculiar complex stomach adapted for water-storage. Widely separated as are the two groups, we can account for the fact.

The case cannot be more succinctly stated than in the words of Dr. Alfred Russel Wallace, who has shown that the discovery of fossils during the last generation in North America makes clear the probable development of the family in that country from a smaller and more primitive type of animal. The strata of the late, middle, and early Tertiary periods reveal early forms combining the characters of all the hoofed animals, from the swine and the hippopotamus to camels, sheep, deer, and antelopes, gradually becoming specialised into these varied forms. It is therefore clear that in all likelihood the camel and llama tribes originated in the central United States, where, towards the end of the Tertiary period, they became extinct. Happily, prior to this catastrophe, some of the true camels had migrated to the Eastern hemisphere, probably by way of continuous land in the North Pacific, and have left as their only survivors the camel and the dromedary. About the same time, and probably driven to migrate by the same adverse conditions which led to the extinction of so many of their allies, the llama group passed southwards along the mountain ranges into South America, where they have found suitable conditions for their survival south of the equator, in the high Andes and on the arid plains of Patagonia. In order that the foregoing should not be deemed too sweeping a life-story of the family, it ought to be added that there is high authority for the belief that possibly the Arabian camel originated in India.

Whatever the place of its origin, we find this animal existing now, not only in Arabia, but in South Africa, where it has for many a day carried the mails in the remoter parts and supplied the police with mounts and hauled their vehicles; in Australia, where it has helped to establish the prosperity of many of our Colonial

cousins, by carrying up-country the wire necessary for fencing out the rabbits, and bringing down the wool upon which the settlers' fortunes are staked. It is bred in great numbers in India; it is an industrious servant in the Canary Islands; it is at work in parts of Italy. Wherever there is dry, sandy land with scanty herbage, or, say, even absence of a wet, cold climate, the Arabian camel can flourish. We rule out sub-Arctic conditions, of course, that suit only the Bactrian camel.

As the camel is so generally employed by man, what is the puzzle to which reference has been made? The puzzle is that man should have evolved an animal at once so valuable and yet so unmitigated a brute. There are bad-tempered and unreliable dogs, horses, cattle, and asses as exceptions, but practically all camels are ill-conditioned, treacherous, and sour-tempered. They seem to go through life with a grievance against all the rest of the world. It is as natural for a camel savagely to gnaw the hand or arm of its master as it is for an intelligent horse to whinny with pleasure at his approach. Well fed, lightly loaded, kindly treated, the camel will "savage" a rider whom it passes on a narrow path.

THE GUANACO

For thousands of years this animal has been domesticated—there is not a really wild Arabian camel in the ordinary acceptation of the term. The great herds that roam unbroken in North-West India, in the Soudan, and in Somaliland are as much domesticated as the flockmaster's sheep. Yet nothing improves the intelligence or temper of the camel. In that respect it is probably unique. Man has improved the intelligence of the horse and dog, and, indeed, that of practically all the mammals he has taken under his control. Perhaps the fault in regard to the camel lies with man. He has bred only with a view to stature, strength, speed, endurance, to milk-giving qualities, to the abundance of hair, but not with a view to developing intelligence; and as the camel is not left to shift for his own living, and escapes, therefore, the stern struggle for existence that wild animals have to brave, he has not needed, of his own initiative, to develop brain-power.

But with all his villainies, the camel is simply indipensable to the East. The British Army has its camel corps. It was the men of a camel corps who fought the terrible battle of Abu Klea, in the Soudan. To the Arab the camel is fortune. It is the only animal that can cross the desert. With its broad pads to prevent it from sinking into the sand, with a nasal defence against the sandstorm rivalling that of the hippopotamus in the water, with capacity unique among domesticated animals for withstanding the effects of thirst, it bears the burdens of the merchandise that has to be carried across otherwise impassable desert.

The camel is not only a beast of burthen to its owner. The swift dromedary, keeping up its eight or nine mile an hour for hour after hour, is the Arab's charger in the wastes. The female camel yields him milk and cream and butter. The milk is rich and sustaining, though it cannot be used in tea or coffee, owing to its curdling. The butter-making is a simple process. Separated cream is put into a skin bag and hung upon the saddle at the beginning of the day's journey, and upon the resting-place being reached the cream has become butter, churned by the action of the camel in walking.

The hair of the animal is woven by the Arabs into cloth, and it makes the best of brushes. The very dung is utilised, and often constitutes the only fuel in the desert. With it the Arab makes his fire to cook his food; and it is betraying no trade secret to mention that the peculiar odour of a certain high-priced tobacco arises from the fumes of fires of this sort, over which it is "cured." The food of the Arabian camel is of the meagrest type. The animal can eat whatever vegetation the inhospitable desert affords. No thorn is too formidable, no vegetation too dry or tasteless. The animal prefers this form of food to others.

Not long ago the present writer stood to watch a camel at liberty in a field of

luscious grass. Horses pastured in the meadow stood afar off, gazing with looks of terror at the stranger, revealing once more that curious antipathy with which the camel always inspires the horse. The camel made straight for the hedge, and browsed upon the thorny growths of which it was compounded; the grass had no meaning for this strange beast. There was water trickling deep down in the ditch, but the camel disregarded this. Now, the camel in the East will only with the greatest reluctance cross the tiniest of streams, showing how persistent is the instinct of this desert-reared mammal.

But, at times, of course, it does have to cross rivers. Slatin Pasha's life, on his flight from the Khalifa's citadel, depended upon his getting his camel over a wide river. His Arab friends saw to that for him. They took Slatin across in a small boat. They emptied their water-skins and inflated them, and tied these about the neck of the camel, and buoyed him over. But that thrilling flight emphasised the inferiority of the Arabian to the Bactrian camel in rocky country. The one camel that Slatin possessed during a most critical part of his journey, cut one of its feet almost to pieces on a rock, and Slatin had nearly to strip himself to bind up its wounds. He had learned the trick at Darfur, where he had seen natives put a sort of shoe upon the injured feet of camels, a shoe of cloth and leather.

The Bactrian camel, instantly distinguishable from the Arabian by the fact that it has two humps, not one, is to cold, rocky and hilly country what its Arabian congener is to the scorching desert. It has shorter and stouter limbs, and smaller, tougher feet. But in endurance it differs little from the other. It can survive the bitterest cold; it feeds upon the sparse herbage of the steppes; and revels in brackish water which very few other animals could drink. It can make its bed in the snow as comfortably as the Arabian animal can in the sand. But it is not indestructible. Col. Fred Burnaby, on his journey to Khiva, found that of 14,000 camels requisitioned for a then recent Russian expedition, nearly all had died from hardship. Still, with reasonably careful treatment, the Bactrian camel is a marvel of endurance at a minimum cost to its master. Burnaby, during part of his journey, was driven, for lack of horses, to have three camels harnessed to his conveyance, and a sorry time they gave him. One was ridden at the outset, but suddenly stood stock still, and shot its postilion into a snowdrift. A second lay down at the first touch of the whip; the third threatened to emulate the performance. Another adventure found Burnaby seated upon the back of a love-sick camel of gigantic stature. This animal became separated from its lady-love, but hearing her grunting and squealing at being saddled, he wheeled round, rearing, and raced like a whirlwind on stilts to her side, nearly shaking the life out of his rider. But love has ears, even in a Bactrian camel.

A YAK FROM CHINESE TARTARY

There are supposed to be no wild camels in existence, but in the desert regions of Central Asia there certainly are wild camels, descended probably from animals that once were domesticated. It is supposed that their ancestors escaped the frightful sand-storms which overwhelmed the district known as Takla Makan, some two centuries ago They have the greatest fear of man, and none of them, so far as is known, has ever been caught, for the simple reason that no horse can approach them in the deep sand of the region they frequent. The Tibetan desert has its free-roving camel, and this, it is thought, may be a veritable wild camel, descended, perhaps, from the stock which early man, thousands of years before history, first tamed.

Asia and Africa give us the biggest members of the camel family, but the South American representatives, though smaller, have something of the family vice. The

A HERD OF REINDEER IN NORWAY

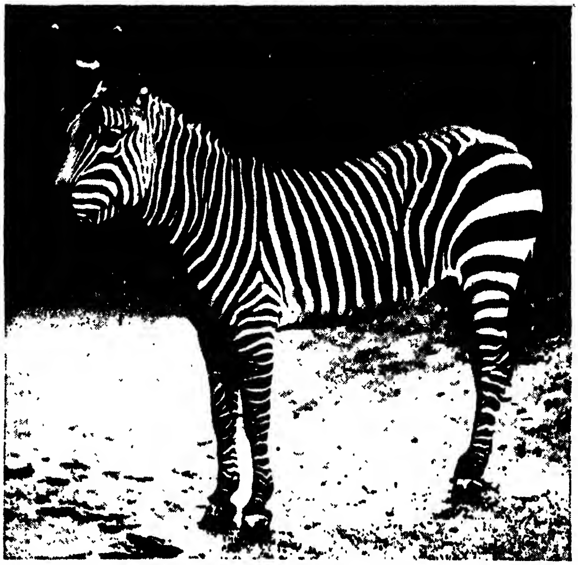
llama is the one animal that spits. It does so with lamentable force and accuracy; and even the petted llama of the Zoolgical Gardens, in London, is an offender, so that he has to have a double rail between himself and the public.

When we speak of the llama we have to include four forms—the llama proper, the alpaca, the guanaco, and the vicugna. The llama and the alpaca are the domesticated members of the group. It seems almost incredible, but the llama was the only beast of burthen in America when the Spaniards first landed. The sight of a horseman filled the Peruvians with terror; such a phenomenon representea a centaur to their imagination. For thousands of years the llama was the Peruvian's steed and pack animal, and the alpaca was his sheep. The male llamas only were taken to work, the females being left then, as now, in comparative freedom upon the hillside, where, during the absence of their lords, they might be visited by the larger and more powerful guanaco. It seems clear that the llama is the domesticated descendant of the guanaco, as the alpaca is the descendant of the vicugna.

The Peruvians looked as carefully to the breed of their animals as we do; indeed, Darwin wrote that they reversed the system of which our Scottish sportsmen were accused in his day, namely, of killing the finest stags, and thus causing their whole race of deer to degenerate. The Incas killed the old and the inferior specimens, rooted out bad colours, and preserved the animals of finest size and form. And that went on until the Spanish invasion. By that time the land possessed boundless herds of both animals. It was not until Sir Titus Salt discovered the value of the

wool of the alpaca that this commodity became marketable in Europe. Nevertheless, Saltaire is founded upon the coat of this "sheep" of the ancient Incas.

All the llama family share the distaste of the true camel for luxurious living. The true llama supports itself on the sparsest of food; the vicugna, when vegetation is plentiful, seeks the higher range of its native mountains, where it is poorest; and only in the heat of summer, when the sun has dried up all vegetation in exposed situations, does it descend to the higher valleys. The guanaco, too, haunts the mountains, where food is never excessively rich. It is this animal, it will be remembered, which has the strange habit of repairing to a definite spot to die. Darwin was the first to allude in print to this remarkable habit, pointing out that he had discovered spots, beneath the thick undergrowth overhanging a river, actually white with the bones of this animal, bones that obviously had not been dragged there, or disturbed, by predatory animals, but were the remains of creatures which had lain down there to die a natural death.


THE MOUNTAIN ZEBRA OF CAPE COLONY

Mr. Hudson, in his well-known work, inclines to the belief that the guanaco, which in time of cold or of illness is wont to seek the shelter of bushes, may be impelled, as death approaches, to seek similar seclusion, and that the animal goes to its sanctuary, not to die, but with a sort of unreasoning remembrance of relief experienced in the same place, and possible expectation of a similar issue.

Highly valued as is the camel family in the Old World and the New, the reindeer runs it close in the esteem of its master, in the northern regions of both the Eastern and Western hemispheres. To the Laplander the number of his reindeer represents his wealth. With a thousand of these animals he is among the plutocrats of the land; the man who owns half as many is of the middle classes; while he that boasts but forty or fifty is content to merge his small herd in that of another, and work for the owner of the greater number. The reindeer has been captured from the wilds, a creature of the tundra, the snows, and the waste places of Lapland. It can draw a heavily laden sledge, or carry a man or a substantial package upon its back, and travel at the rate of eight to ten miles an hour for several hours in succession. Its advantage over the dog is that it finds its food where it rests, while the food of the dog must be taken with it. But the reindeer yields milk and meat, hide for boots, clothing, bedding, the tent and the boat, and its sinews serve as ropes. The Laplander learned to extract every ounce of value from this animal long before the scientific American butcher set up his laboratory for converting cattle to a thousand uses.

Seeing that the reindeer is to him horse, cow, sheep, and goat, it is strange that man has not improved the animal more, but it is a fact that the domesticated reindeer is never so fine an animal as its free relative. This is especially the case in Lapland. In Siberia, too, where the domesticated animal is bigger than that of Lapland, it is smaller than the one that roams at large. Doubtless this is owing in the main to the wider, indeed unrestricted, range of the free animal. He roams at will up the mountain side in summer and descends to the plains in winter.

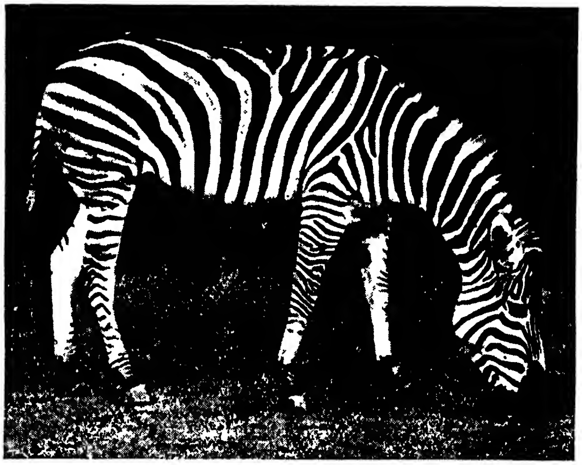
Where sheep and cattle would starve he finds a generous diet of lichen, or reindeer moss, and other rough herbage. When hard pressed the reindeer will even pose as a carnivore; and, in time of famine, when the lemming is on the march, reindeer eat hundreds of thousands of these little rodents, a fact matched by the circumstance that in the hard winter of 1894-5 stags in Aberdeenshire were known to eat rabbits.

The reindeer's is a hard life, but he is beautifully fitted for it, and on the whole his lot, it is pleasant to reflect, is not worse with man than when he is in a state of liberty. Indeed, we may claim to have done something to keep him alive, for this animal is sadly subject to anthrax, a disease which has in the past carried off enormous numbers.

Happily the scientist has come to the aid of the Laplander and the man of Siberia, and has taught him to inoculate his herd, so that this deadly plague need no longer rob him of his all.

The reindeer seems to have a still more widely extended dominion to conquer. Thanks to the indomitable Dr. Grenfell, it has been introduced into Newfoundland and Labrador, where it is thriving wonderfully. Canadian Eskimos are taking up reindeer-keeping, and the Dominion Government has recently begun experiments on a wide scale. Should results in this direction be satisfactory, probably the Canadian Government will feel justified in extending their operations, and adopt a suggestion to import the yak for the Barren Lands.

This animal, peculiar to the elevated plateau of Tibet and the adjacent districts of China, exists in freedom in vast numbers where it is not frequently hunted. It is an indispensable member of the circle of domesticated animals. It seeks the wildest, most desolate regions in the inhospitable country to which it belongs, and can endure an extraordinarily low temperature on the roughest diet. It has long been bred in captivity, and man has brought his art to bear to modify the characteristics of the animal. By introducing into his herd of yaks the blood of the true cattle, he has succeeded in producing an animal that can bear heat as well as cold—an advantage the true-bred yak does not possess. The yak, which is a massively built animal, reaching a weight of 1000 pounds and a height of six feet, can carry heavy burdens over mountain roads that puzzle even a mule.



THE QUAGGA OF DAMARALAND

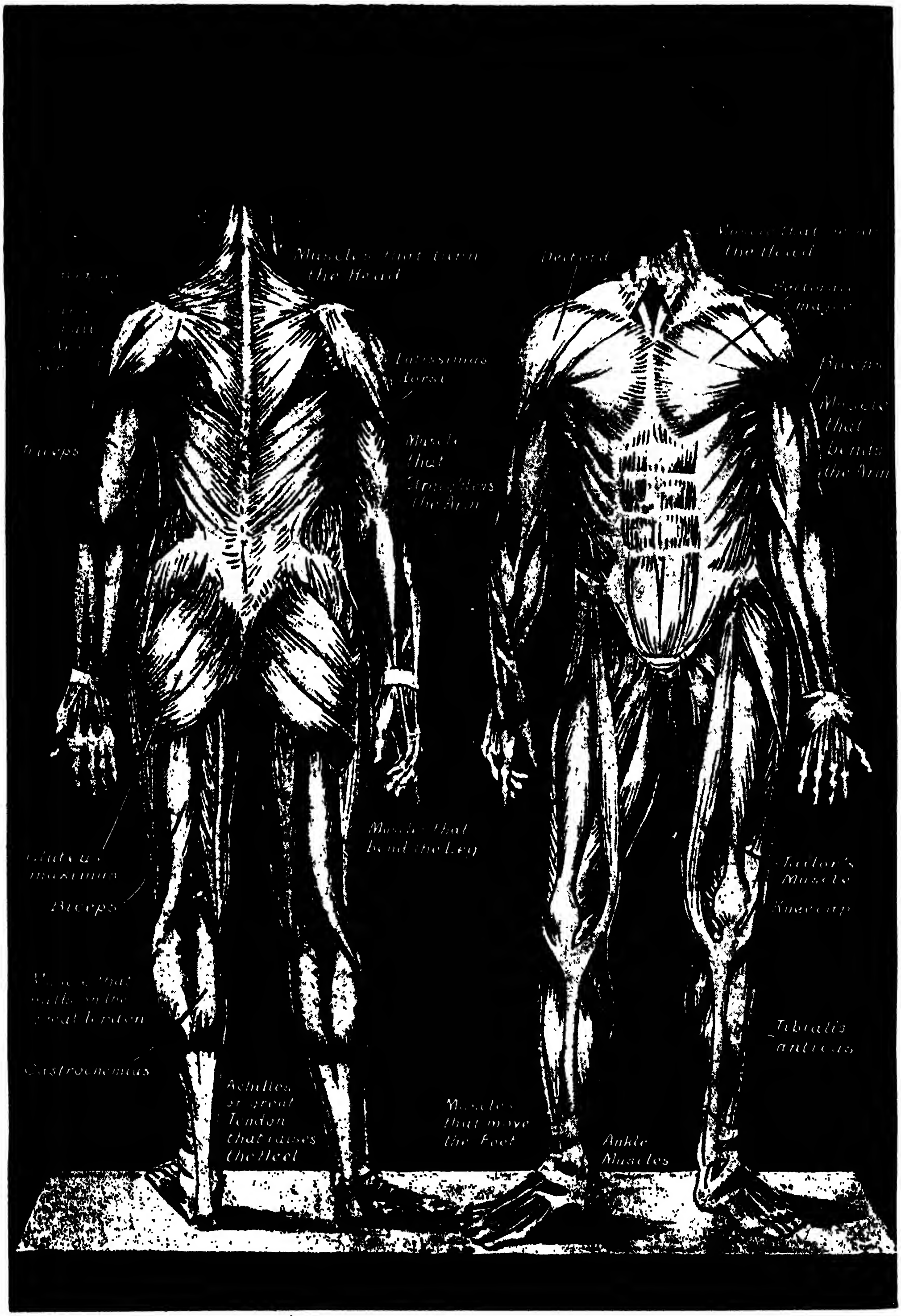
The British mission to Tibet in 1904 learned to their cost that the yak, hardy as he naturally is, cannot be submitted without great peril to exacting marches through varying temperatures and unusual conditions. Four thousand of these animals were collected in Nepal, and only 150 survived the expedition. They were allowed by their native drivers to drink infected water in Nepal. Anthrax broke out, followed by rinderpest, and foot-and-mouth disease. Hundreds died from heat and cattle plague in the deadly, sultry valleys of Sikkim, and the march of the yak corps was marked by a long line of deaths. But this sad experience is of the kind that Britons must buy when they first take over the animals that other nations have domesticated. Such a thing never could, or never should, happen again.

There remains only the zebra group for consideration in our list. Here we have the quagga, distributed over an enormous area of East Africa, from Abyssinia to Zululand, and thence westward to Southern Angola; the mountain zebra, now reduced by shameful slaughter merely to a few protected herds; Foa's zebra, a rare species, and Grevy's zebra, the largest and finest species of the group, an animal measuring 13 hands, or 52 inches, at the withers. The zebra, as we have seen, has been broken to harness, and is impervious to the deadly tsetse fly.

Colonel Sir David Bruce has newly arrived in Nyasaland on his third campaign against sleeping sickness, and if he succeeds it should not be difficult to render animals immune. Be that as it may, the zebra has high economic possibilities; and the killing of it ought to be as unlawful as the killing of ponies in the New Forest. Had it been an Asian animal, the zebra would have been tamed ages ago.

It is hardly necessary to add that the zebra and quagga, with the ass, are all members of the horse tribe, and merit the consideration due to kinship with one of the most faithful animals trained to aid humanity.

THE MUSCULAR SYSTEM OF MAN



THE PRINCIPAL PARTS OF THE NATURAL MACHINERY THAT WORKS THE HUMAN BODY

MAN'S THEWS AND SINEWS

How Our Muscles are Fed, Increased, Held in Reserve, Used, Poisoned, Purified, and Controlled

THE MARVELLOUS MACHINERY OF THE BODY

THE bony framework of the body, its joints, and the muscles which act upon them, constitute, from one point of view, a single system, the function of which is mechanical and motor. No less just is the view which looks upon muscles as simply the "end-organs" of nerves—as merely the mechanical structures developed at the ends of motor nerves to do their bidding. Looking at the body as a whole, and trying to grasp broadly what has been called the "philosophy of the organism," we must retain both views.

Primarily, muscles are for motion, as bones are for stability, though we saw that bones have a secondary function which is no less essential to the maintenance of the body, and we shall find that the same is true of muscles. The motion is almost invariably that of one bone upon another, or of groups of bones upon each other, but there are some interesting exceptions which may be briefly noted—exceptions none the less interesting because they partake, in some degree, of the character of ancestral relics, or survivals. The muscles in question are superficial, and their business is with the skin or its appendages. A possible advantage of being able to twitch the skin is that it affords some protection against insects, those great enemies, from the invertebrate world, of the back-boned forms in which life has chiefly ascended.

Thus, the horse has an entire sheet of muscle covering its body, and this is represented in ourselves very imperfectly, first, by a thin sheet of muscle in the neck, and second, by a tiny scrap of muscle, the presence of which any of us can infer for himself, if he will look at the skin on the inner side of the palm and try to wrinkle it. The muscle in the neck has the power of contracting the skin there; it is supplied by the nerve of expression, and comes into the group recognised by Darwin as the muscles expressing anger. Its action may sometimes be seen in an angry dog, but it is seldom or never thrown into action by man, even when angry.

At a somewhat deeper level are certain other muscles, which are also unconnected with the bony system, and do not act upon joints. There are thus three scraps of muscle attached to the outer ear, on either side of the body, which in former days would have been employed for the detection of the direction of sound, and for its more easy reception, but they are also decadent in man. Much more important are the superficial muscles of the face and lips and scalp, and the muscles around the eyes. These form a complex and important system, all controlled by the nerve of expression, and all extremely well supplied with fibres from it, in proportion to their very small bulk.

They are essentially the social muscles, for in the absence of anyone to impress there is no occasion to express, and their functions are almost wholly those of expression. Thus, the upper eyelid naturally falls, by its own weight, if it be not raised by the special muscle which is attached to it from behind. The muscle which encircles the eyelids and can "screw up" the eyes, is not required for simple closure, but has considerable functions for that intense closure which expresses an emotion of horror or disgust. Life is persistently economical, and no doubt the muscles of the lips, for instance, are employed for more purposes than expression; but the general statement is true that expression is the primary function of the muscles of this group, and only on the ground of the *finesse* of expression and the incredible minuteness of difference between its shades can we account for the very rich nerve-supply of these small structures.

It seems fair, also, to include the muscles associated with the hairs in this category or near it. They are very tiny, and lie nowhere near bones or joints. They are no more under the control of our will to-day than the muscles of the outer ears, but it may be that the power of throwing them into action voluntarily exists among the lower animals. It is not in a sentence, however, that we shall decide whether the cat elevates its hair in order to frighten its enemy, or as an inevitable expression of the emotion called anger, or partly for both reasons. At any rate, man has muscular slips attached to his hairs, and on occasion they act, and his "hair stands on end." We shall agree that these occasions are emotional, and that this classification is, therefore, probably just. The phenomenon called "goose-skin" also depends upon emotion, and is due to the activity of these muscles.

So much for the superficial muscles, sheets, slips, or what not, which persist in man, and have nothing to do with bones and joints, but are concerned simply to move parts of the skin or its appendages.

The Muscular System that has been Placed Beyond the Control of Our Will

But there remains a great group of muscles, or muscular tissue, which is not concerned with bones and joints, nor with movements of the body as a whole, nor, indeed, with any act or possibility of the conscious will, but which are, nevertheless, necessary to life.

When we study muscular tissue under the microscope, we find that some specimens of it are marked by a series of transverse stripes, running across the long direction of the fibres (or of the muscle cells, as indeed they are), whereas other specimens are unstriped. We further find the remarkable fact that the striped structure always comes from the muscles which we use voluntarily, while the unstriped structure comes from muscular tissue which is not under the control of the will, and the existence of which is probably unknown to most of us. Unstriped or involuntary muscle can only be discussed in outline here, because it is concerned with internal organs, of which we should require to know something first; but it is very necessary to realise that muscle is essentially muscle everywhere, having structure fundamentally the same in all cases, and the function of producing movement.

The most important instance of unstriped or involuntary muscle in the body is that which composes practically the whole thickness of the walls of the heart, and which contracts oftener than once every second from many months before our birth until death. The microscopists report, however, that the heart muscle is in some degree unique, being apparently intermediate, in the minute details of structure, between striped and unstriped muscle. Though breathing is necessary, and proceeds without the attention of the will, the muscles of breathing can be stimulated voluntarily and are all composed of striped tissue; thus the diaphragm, or midriff, after the heart the most important muscle in the body, is definitely striped.

How the Muscular Coats of the Blood and Air Passages Act Involuntarily

But the circulatory system contains unstriped muscle in every part of it except the minutest hair-like vessels, and this muscular tissue constitutes a coat which regulates the size of veins and arteries, not only apart from the will, but often against it, as when we blush in spite of our best efforts not to. The respiratory system also has important examples of unstriped muscle, controlling the size of the air passages in the lungs, after a similar fashion to that of the arteries and veins. Here, again, we find that the tissue is not subject to the will, and may even contract against it, as only too often in the malady called nervous asthma, where the difficulty of breathing depends upon the involuntary and morbid action of the unstriped muscular tissue in the walls of the air vessels.

The Apparatus of Digestion and Its Automatic Working

No less important is the unstriped muscular tissue in the walls of the digestive canal. The gullet is thus lined, and though we swallow voluntarily, and by means of striped muscle, it is unstriped muscle and involuntary action that drive the food from the beginning of the gullet into the stomach. That receptacle is similarly lined, and the lining is invaluable in stirring the stomach contents during digestion. For many yards thereafter the digestive canal proceeds, lined with unstriped muscle throughout. And in various other parts of the body we find unstriped muscle, as, for instance, in small quantity behind the eyeball, which it may cause to protrude; in the wall of the uterus or womb, and elsewhere.

Though the whole system of unstriped muscle is beyond the reach of the will, it is not independent of nervous control. There are certain agents, such as forms of

electricity, which can stimulate muscular tissue directly, without nervous intervention. But such stimulation never occurs in the normal life of the body. All muscle cells whatever are the end-organs of nerves, as we began by saying, and normally they neither act by themselves nor in response to any but nervous stimulation. This has lately been proved true even of the muscle of the heart, which many have long supposed to be independent of nerves altogether, so far as the origin of the beat is concerned, though we know, of course, that nerves can and do affect the beat. It is true that the heart continues to beat though all the nerves running to it be severed. But this beat is not originated by the muscle itself, but by special groups of nerve cells which are found in the substance of the heart. It is definitely proved, then, that muscle originates nothing. It is always and only a servant, and in the natural life of the body it takes orders from nerves only. The involuntary or unstriped forms of muscle are just as much subject to the central nervous system, including certain portions of the brain itself, as are the muscles of the fingers, but the conscious will does not reach them.

This is very far from saying that consciousness does not affect them, or that they are independent of anything that happens in the uppermost part of the brain. We have already noted, for instance, how feeling may cause a blush. And we now know ways in which these involuntary muscles may be controlled and willed to do what we will, though the will of their owner is not concerned. That will is indeed the obstacle. But if the person be hypnotised or, short of actual hypnotism, be put into a state in which the will is, as they say, "short-circuited," or evaded, or put to sleep, then ideas put into the patient's mind, either by himself for himself, or by someone else with his approval, can directly control the working of the involuntary muscles thereafter. Thus, for instance, asthma may be controlled, or the movements of the digestive tract, and those results may be attained which the utmost efforts at willing on the part of the patient made only more impossible. This is not the place in which to look more closely at these astonishing and only lately defined facts; but we must note them here when we speak of unstriped muscle as involuntary. Involuntary it is, but inaccessible to the will, by denial of the will, it is not—curious and significant paradox.

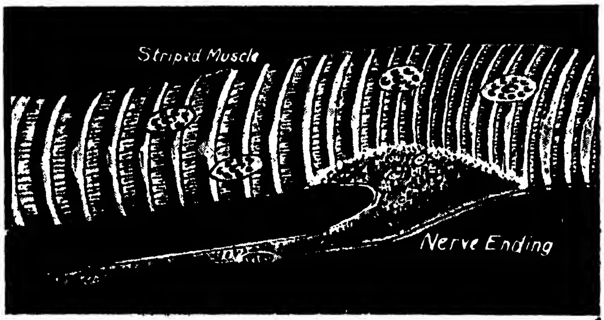

THE MUSCLES OF FACIAL EXPRESSION

In the essentials of microscopic structure, all forms of muscle, striped and unstriped, agree. A muscle is essentially a group of elongated living cells, very long and narrow, each with a nucleus, and each bound to its neighbours and arranged lengthwise in the direction in which the muscle is required to pull. These cells are supplied with nerves, the proportion of nerve to muscle varying widely. As much nervous tissue, for instance, may be found in a small muscle of the ball of the thumb as in a large muscle of the thigh. The proportion of nerve would therefore seem to depend on the variety and delicacy of the movements which the muscle will be called upon to perform. Or perhaps we should reverse the statement, and say that the richly innervated muscle is that which we can put to the most delicate and numerous uses. Muscles are further endowed with a second and wholly distinct set of nerves, which are entirely different in function from those just named.

The first and most evident group of nerve fibres found in muscular tissue is motor in function, and these constitute the "nerve supply" of a muscle in the ordinary use of that term. If these nerves be stimulated the muscle fibres contract; if they be divided the muscle is paralysed. But we have lately learnt that all muscles are supplied with a second set of nerves, whose function is not motor but sensory. These nerves feel, and that which they feel appears to be the exact shape and condition of the

muscle at any given moment. They keep the central nervous system informed as to the whereabouts of its servants, and their obedience or disobedience to its orders.

A certain amount of connective tissue, loose or strong in structure, lies between the fibres of a muscle, and binds them together. This connective tissue is found in almost all parts of the body, and performs the functions of packing and binding. It is found, also, spread over the surface of muscles, forming a kind of sheath or outer coat inside which they work. Connective tissue cannot contract. If muscular tissue degenerates, from any cause, and there are many, its place is often taken, in some degree, by an increase in the amount of connective tissue within the muscle. Thus the bulk of the muscle may be maintained, or even, in some cases, increased; but such a muscle, which may be that of the heart, or any other, is worth little, for no connective tissue, however strong, firm, and dense it may be, can contract, and the muscle which cannot contract is nothing.



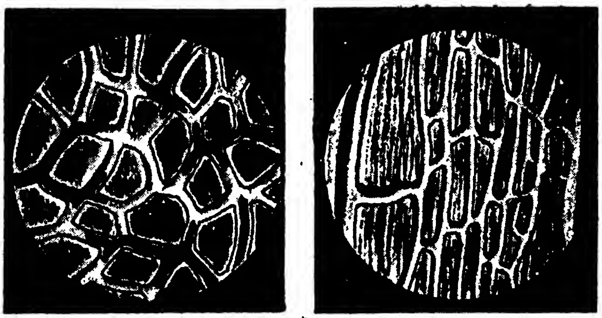
PORTION OF MUSCLE FIBRE, SHOWING HOW THE NERVE IS ATTACHED

The study of development teaches us that muscles are essentially formed from small, roundish, nucleated cells, which become greatly elongated, are arranged in parallel bundles, and acquire the power of contraction. There is evidence to show that certain numbers of these cells occur, in an undeveloped, and thus useless, form in adult muscle; just as we shall discover in due course that a certain number of undeveloped nerve cells occur in the adult brain. In both these cases, and especially in the latter, the facts are evidently most suggestive and important, bearing as they seem to do upon the possibility, utility, and limits of education. Unfortunately, we know too little yet of this fascinating subject. But it would appear that a certain number, probably definite and limited, of these cells are found in all or most muscles, and that under certain conditions they are capable of development, even in maturity. It looks as if they constituted a natural reserve for emergencies. The intense economy of life forbids their development without occasion, but if we set ourselves to physical development and training we develop these cells and our muscles grow larger. There are many people who become definitely heavier under the influence of exercise, no less definitely than those who lose weight; and the increase of weight is due to the actual development of new muscular tissue. It appears that individual muscular fibres do not much enlarge, if at all, and certainly new ones cannot develop from anything but cells predestined to become muscle fibres if they develop at all, and that is what happens.

All this throws much light on many familiar facts of physical development which we too often forget. The same conditions, applied to different people, produce different results; nay, if each be given the conditions best suited for himself and himself alone, the results are still disproportionate. Probably the natural endowment of potential muscle cells is unequal in the two cases. And, further, for each of us there is a natural limit of muscular development which we cannot transcend, as many a disappointed aspirant to muscular honours has discovered. The foregoing theory would suggest an evident interpretation—that one may, by labour and suitable nourishment, develop every possible muscle cell in one's body into an active, contractile muscle fibre; but when that has been done, nothing whatever will make us any stronger. If these simple and reasonable considerations were known to any but a few physiologists, much injury of many kinds, especially to growing boys and young men still short of complete development, might be averted; which end may these pages serve.

It must be remembered, also, that the normal body is not constructed and developed by fits and starts, without balance between its parts, but is a co-ordinated whole. There is normally an adjustment between the size of bones, the size of muscles, and the blood supply of both. To develop muscles unduly, while proportionate enlargement of the bones is impossible, may be useless and dangerous,

To develop the muscular substance of the heart, while the size of the arteries which supply that substance with blood remains unchanged, may simply be to ensure subsequent degeneration, probably not long delayed; and the last stage of that heart is much worse than the first. From this understanding of the "philosophy of the organism" there follows the important truth that the just period for physical development, an admirable and useful thing in its way, is during the early years of growth and construction of the body as a whole. Growing bones can respond to use and exercise and the increased blood supply which these involve; but the length, for instance, of adult bones is determined for ever. And the further principle may be inferred, that since the body is a purposeful whole, the best manner of developing any portion of it, such as the muscles, is not to isolate that portion and concentrate upon it, but to put the body as a whole to those purposes which require the use of the portion in question. The upshot of which is, in a word, that youthful play is the one and only perfect and natural way of developing a fine physique.



TRANSVERSE AND LONGITUDINAL SECTIONS OF A MUSCLE
Showing the network of capillaries through which the blood flows from the arteries to the veins. The transverse section is on the left; the longitudinal is on the right.

Our statement of the constitution of muscular tissue, striped and voluntary, or unstriped and involuntary, is not complete unless we mention the supply of blood vessels which every muscle requires, and also the supply of lymph vessels, or "lymphatics," upon which chiefly devolves the function of carrying away from the muscle certain of its waste products. The circulation in the lymphatics is markedly improved by movement, and languishes when muscles are not employed. But "passive movement"—*i.e.*, being moved—and intermittent pressure largely succeed in keeping the lymphatic circulation sufficiently brisk, and this physiological fact largely underlies the well-known utility of massage, especially for persons who, for any reason, are prevented from using their muscles and promoting the lymphatic circulation in the ordinary way.

Such being the various constituents of muscular tissue, we must face its characteristic and astonishing problem, which is its power of contraction. Where the muscle may be, what it pulls upon, whether stimulated through the will or without it or against it—these differences matter not. We may take any single muscular fibre anywhere, from whatever source, and consider its case, provided that we consider along with it the nerve fibre that supplies it, for a muscle, we repeat, is the end-organ of a nerve. It is a simple matter, having first killed such an animal as a frog, to remove a muscle and its nerve from one of the limbs, and to keep them alive for some time, especially if they be kept moist with water containing a small proportion of salt. This is called a "nerve-muscle preparation," and we have not yet learnt the last lesson which it is capable of teaching us.

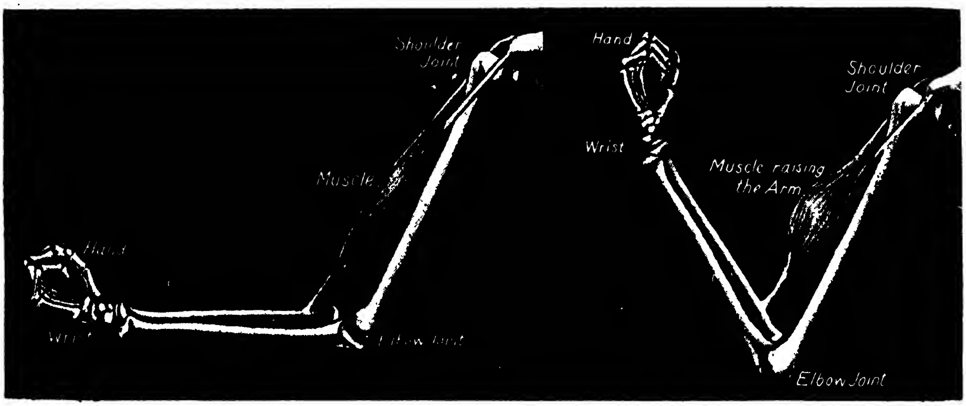
The chief facts which such observations, aided by the microscope, have elicited hitherto are as follow. The muscle fibre shortens and thickens when it contracts. The contraction normally follows upon the stimulation of the motor nerve of the muscle. Contractions which appear to be due to direct action on the muscle itself are almost invariably not so, being really due to stimulation of the nerve endings in the muscle. Galvanic electricity, however, can stimulate muscle directly. Hence its medical use in maintaining the nutrition of muscles whose nerves have been thrown out of action, until such time as those nerves recover. The response of the muscle to nervous stimulation is quick, but not instantaneous; there is a latent period, which may last for perhaps one-hundredth of a second. During that period, of course, rapid and essential chemical processes are occurring in the protoplasm of the muscle fibres, processes which it was the business of the nerve to initiate. This latent period is capable of much variation, and is longer, for instance, in fatigued muscle.

There is no limit, however, to the inquiries which can be made at this point, for there is the whole range of drugs and

food materials with which to experiment, observing their action on the stimulation of the muscle, upon its fatigue and recovery, the rapidity of its contraction and relaxation (which is mostly due to elastic recoil), its response to poisons, stimulants, and narcotics, and to different kinds of food, and at various levels of temperature. A little writing point can be attached to the muscle, and made to mark the records of its successive contractions on the blackened surface of a revolving drum, the rate of which can be controlled, while a tuning fork, or some other device, may register fractions of seconds beneath the record made by the muscle itself. The stimulation of the muscle can be controlled by an electric switch, and with such an apparatus as this a lifetime may easily be devoted to research which ever more and more helps us to understand the nature and conditions of our lives.

A contracting muscle does work, spends energy, for it moves things—itself, if nothing else. Like any other machine, it therefore requires to be supplied with energy, which in the case of a muscle we call food, and in the case of a steam-engine we call fuel, but which is essentially the same in both cases. The principal fuel of muscles is sugar. The starch and the various forms of sugar in our diet—as also, if necessary, parts of the proteins or albumins of the diet—are all converted into a definite and characteristic form of sugar which is called glucose, and is a normal and necessary constituent of the blood. Glucose is the special food or fuel of all muscular tissue, voluntary or involuntary, including the heart; and the modern results of physiology in this respect are already modifying the official dietaries of Germany and Japan. The blood which enters a muscle carries glucose, and doubtless other substances, to it, and the nervous stimulation of a muscle is like the spark to tinder, or the blow to dynamite.

So far the facts are clear and simple. But it utterly passes the wit of man to understand how the necessary explosion or combustion occurs. It must evidently be extremely rapid. No doubt there is a good supply of oxygen, gathered from the blood, and stored ready in the muscle-cells, in some form or other. But that scarcely takes us any nearer towards understanding how it is that the glucose and other fuels of muscle are able to burn, so rapidly and completely, at the mere temperature of the body—which may, remember, be a cold-blooded body—and in a state so far from dry that the whole thing occurs in a tissue which is some three-fourths water. Nor do we understand at all what happens to the substance of the muscle, when the combustion occurs, so as to shorten its fibres, nor how this change is undone, in a tiny fraction of a second, so that the muscle returns to its former state. There is a key to these facts, and it is contained in the word ferments. Only by the intervention of ferments can these processes be set in motion, and only by the study of ferments shall we now get much further in explaining them. Meanwhile, the method of research above outlined provides us with a great multitude of descriptive facts, to which posterity will find the key.

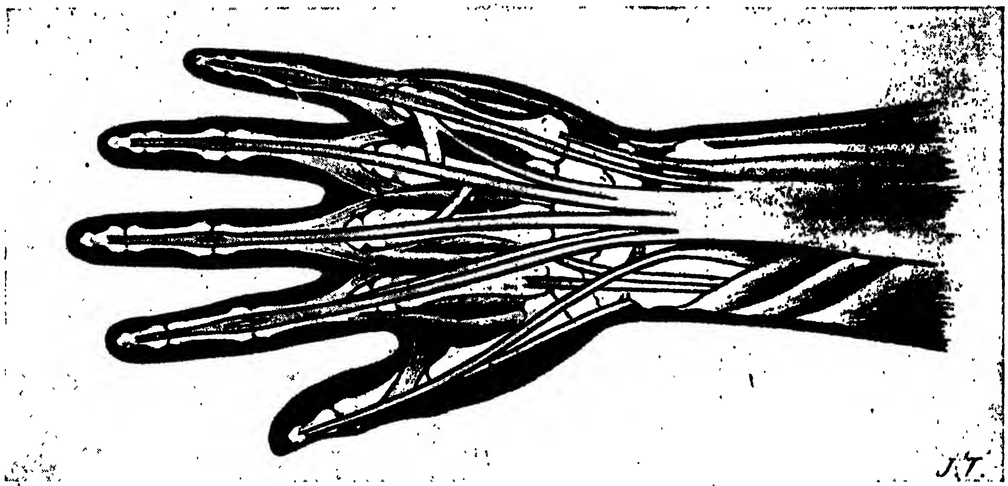


A DIAGRAM SHOWING HOW THE BICEPS MUSCLE RAISES THE FOREARM

A contracting muscle produces chemical substances which have to be disposed of, like the combustion-products of any other machine. The stream of blood leaving a muscle carries away the carbonic acid gas which is the chief result of combustion here, as in every other case where carbon is completely burnt and carbon is one of the chief constituents of glucose. Water is

also produced, by the combustion of the hydrogen which is also contained in glucose, and that is easily disposed of. But there remain a number of other products of combustion, which we can scarcely yet identify and name, but which are certainly very real, and which tend to accumulate in a muscle. After a while, unless they be renewed rapidly enough (as occurs between the beats of the normal heart), these waste products clog the machine, so to say, and interfere with its working. The muscle becomes tired.

We have here made a definite assertion as to the nature of muscular fatigue, which requires justification. The fatigue of a muscle, which we can observe in the successively shorter and slower strokes written by it upon our drum, or by means of a similar apparatus connected with the human hand or finger, may imaginably be due to several causes. We require to discriminate between exhaustion of the nerve cells which rule the muscle, exhaustion of the nerve fibres which run from nerve cells to muscle cells, starvation of the muscle-cells, and their poisoning by their own products. Of these possible factors of muscular fatigue, the first and fourth have been verified. Nerve fibres do not get tired, and muscles grow tired long before they have exhausted their supply of food or fuel. Muscular fatigue, on the contrary, is partly nerve-cell fatigue, as the microscopic and chemical examination of long stimulated motor nerve cells proves. It follows that muscular fatigue takes much longer to occur when we observe it in a nerve muscle preparation, where no nerve cells are involved, and their place is taken by an electric current which does not tire. But even so the muscle becomes fatigued in due course, and we find that its fatigue is essentially a toxic symptom—due to poisoning. Thus we can start the muscle again by washing the poisons out of it. Thus, also, the injection of a portion of the blood of a tired dog into the body of a rested dog will induce at once the symptoms of physical fatigue. Thus, also, we find the key to the control of fatigue by, for instance, hot drinks or anything that stimulates the circulation, for this means that the fatigue products will be more quickly removed by the blood stream from the tired muscles. Thus, again, we understand the remarkable influence of massage upon fatigue. Massage and passive movement do not involve the contraction of the muscle, and therefore do not add to its intoxication; but they do what its contraction normally does—they squeeze the lymph vessels and greatly promote the removal of those fatigue poisons which find their exit from the muscle by this route.


THE MUSCULAR TISSUE AND BONES OF THE UPPER PART OF THE HAND AND WRIST

So much for muscles and their physiology in general, and now we must look at the striped or voluntary muscles which constitute so much of the bulk and weight of the body, and by which we move and realise our purposes. By far the greater number of them are attached to bones, and pass over joints, upon which they act. The point or surface which is usually fixed when a muscle acts, and to which it is attached, is usually called its origin, and the point which is moved is called its insertion. But one may reverse these relations. Thus the biceps muscle, on the front of the upper

arm, bends the elbow joint, and normally its attachment to the forearm is its insertion. But when we pull ourselves up on a bar, or when we climb, the forearms are fixed, and it is the heads or origins of the biceps—*i.e.*, the two-headed muscle—that are moved.

The details of the muscles can only be learnt by long and repeated dissection, though the artist may learn something of them from the point of view of surface mouldings. What matters for us is that muscles are of all shapes and sizes, and that a typical muscle has a kind of rope at either end, and a fleshy part, known as its belly, in between them. This fleshy part is the muscle proper, and all flesh, properly so-called, is muscular tissue, though we say that a man is putting on flesh when we really mean that he is putting on fat. The contraction of the belly of the muscle brings its ends together, moving the intervening joint or joints, and this action is that of a lever. The biceps, for instance, illustrates the mechanism of a lever, the elbow-joint being the fulcrum, the point of insertion being the site of the power, and the hand and its contents being the weight.

The Real Meaning of the Strenuous Old Words Thews and Sinews

The ropes of a typical muscle are called tendons. This is the right meaning of the word and none other. The fibrous structures which enclose and bind a joint are not tendons but ligaments, the two words containing respectively the ideas of stretching and binding. We can all feel tendons upon the front of the wrist, and see them upon the back of the hand or corresponding surface of the foot. The old English name for tendons is sinews, and also nerves. A nerve and a tendon may look and feel very similar. The gross ignorance of former days in regard to the elements of anatomy is well reflected in our language. Such words as thews and sinews and nerves have all been used with transferable meanings, though nowadays the two former should certainly be confined to the tendons of muscles. The assertion that an author writes "nervous English" does not mean, as might appear, that he is timid, but, on the contrary, that his writing is abundant in strong structures like tendons, and is thus courageous. But few who use the term understand its origin and connotation.

Though the muscles of the limbs, such as the biceps, are typical, many other types exist, notably the flat, expanded muscles of the abdominal wall, which exert their action by means of flat sheets of fibrous tissue, called aponeuroses, in place of tendons. These muscles are no less important as holding the body together during rest than in their function of moving the trunk, and the question of what is called their "tone" is of high importance from the point of view of the bodily contour, and also in promoting the health and proper functioning of the abdominal contents. Other muscles have very little that can be called tendon-structure at all, such as those short strips of muscular fibre which run up and down between successive ribs and play their part in respiration.

That Worried Look which Tells the Tale of Want of Muscular Tone

A voluntary muscle which is not contracting under the influence of the will has yet a certain tension in it, just like the involuntary muscular fibres which we find in, for instance, the blood vessels. If the nerve to any voluntary muscle be divided, it slightly relaxes. This continuous condition of slight tension is called the tone of the muscle. It is relaxed during sleep. The tone of the muscles is a notable fact and must have meaning, but the subject is somewhat obscure. There can be no doubt as to the use of the tone of the abdominal muscles; and in many cases one of the first steps necessary for the cure of constipation is to restore the tone of the muscles which are failing to keep up the due normal pressure upon the abdominal contents. The tone of the facial muscles is intensely sensitive, and there is scarcely a better index to the state of the health, or a more tell-tale criterion of difference between youth and age, peace and worry of mind. The haggard, jaded, "old" look too commonly observed is due to the relaxed tone of muscles which should be braced. Of course, everything sags, cheeks, mouth corners, and lower lip, and the tissues round the eyes, when the facial muscles thus fail.

The Muscular Energy that Becomes Transformed Not Only into Force but Fire

It may also be the case that the tone of a muscle prepares it for contraction and abbreviates the latent period; a theory which is naturally suggested by the case of the runner who stretches himself, or doubles himself tense, in order to lose no time in starting when the pistol fires. Lastly, it is more than probable that the tone of a muscle involves some degree of combustion, and thus produces heat, which is necessary for the life of, at any rate, warm-blooded creatures such as ourselves.

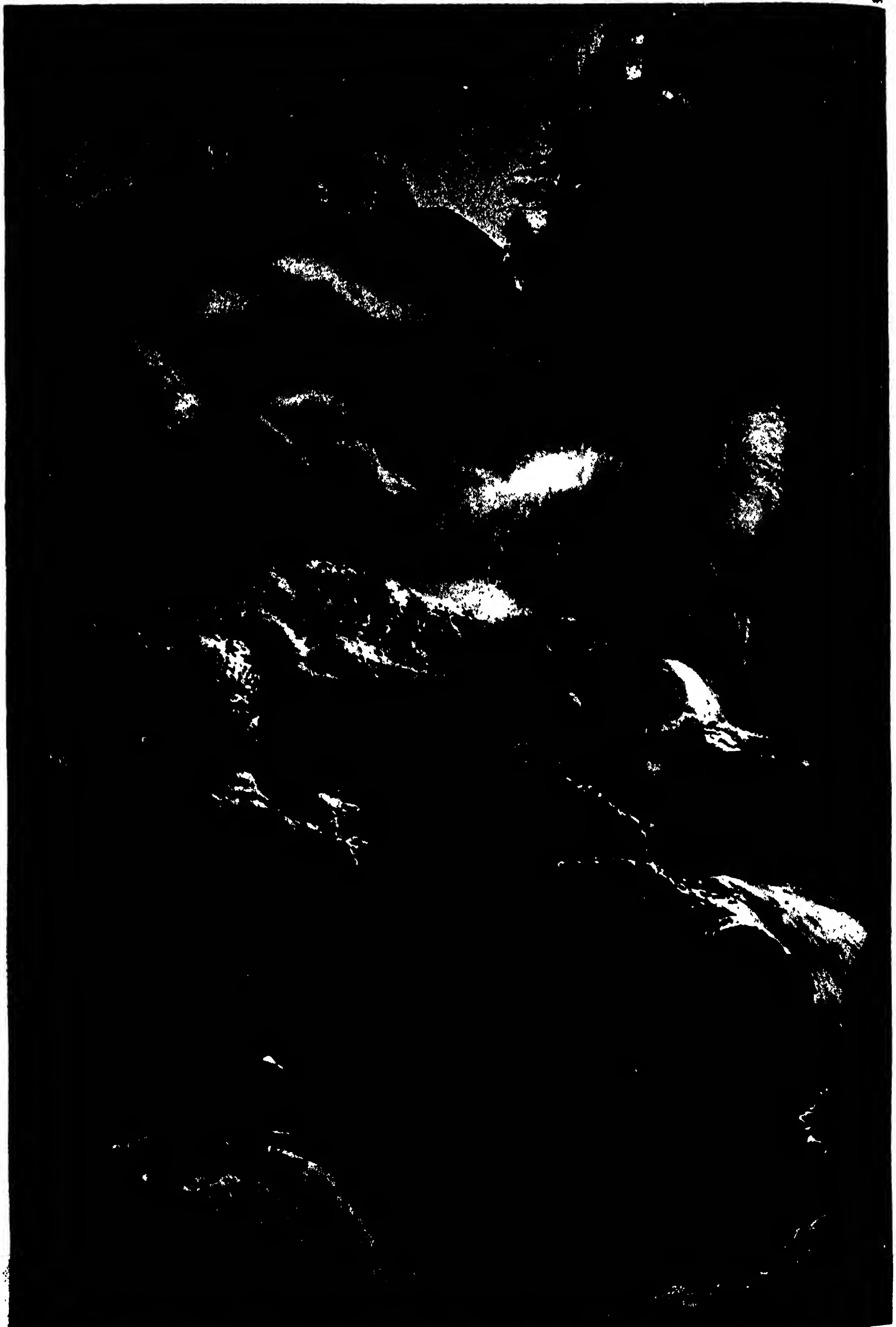
This brings us, in due order, to our final oint—that second function of the muscles, which is also vital, as we found in the case of he bones. They keep the body warm. It s a fact familiar to every engineer that he nly gets a portion of the energy he puts nto his machine back as work or useful notion. By far he greater part s converted nto heat, which s useless and vorse than useless or his purposes. So, also, with the nergy transormed in the combustion processes f muscle. Only a raction of it is ransformed into vork—perhaps bout fifteen per ent., according to ne estimate. The emainder is urned into heat, ut this heat is neither wasted, nor loes it interfere vith the mechanial action of the nuscle, as the heat leveloped in an rdinary machine o often does. On he contrary, it is ll employed in naintaining the emperature of the ody, or of the lood, and through t, of the body at arge. The blood hat leaves an ctive muscle is lefinitely hotter han that which nters it. The nuscles are thus he fireplaces of he body, and perform a second function no ess vital than their first.

There is a widespread popular delusion o the effect that the processes of life are vasteful, extravagant, super-abundant, and ncontrolled. Nothing could be further rom the truth. Life has "drive" and "push" and "thrust," life is impatient nd likes short cuts; but it hates waste.

THE MAN OF MUSCLE, HERCULES SUPPORTING THE EARTH
From a Florentine bronze of the sixteenth century

When we see what we call waste, we must look again, and will seldom fail to be rewarded. The combustion processes within a muscle afford an admirable illustration of the just economy and marvellous adaptability of life—an illustration superior even to that of the bones. Needless to say, the facts of muscle combustion afford the key to the best method of keeping warm and restoring the circulation in cold weather; and they also explain, in part, why we need to cover ourselves with extra clothing when we sleep.

In the foregoing we have considered muscles themselves, and their contraction in itself. Only when we study the nervous system can we learn how this power of contraction is really employed by the body for its purposes—in a fashion far unlike that of the contractions experimentally induced by the physiologist. He can isolate and study an individual muscle, and learn much therefrom; but muscles do not act individually in the living body, except in cases of disease. Muscles act in co-ordinated groups, for the performance of definite actions that achieve things, such as grasping and walking; and the group action of one set of muscles involves, as has lately been discovered, a group action of another kind on the part of the opposing set of muscles; otherwise our doings would be spasmodic and unmanageable. For a muscle is simply the end-organ of a nerve.



Water, so beautiful in sky and earth, passing from sea to atmosphere, from atmosphere to earth, and from earth again to the sea, streams equally in its universal course through all plant and animal life. This photograph of the beautiful falls of the Bernina, in the Engadine, is by Mr. Donald McLeish.

THE STREAM OF HEALTH

The Great Purifying and Renovating Action of Water While We are Well and in Disease

THE REMOVAL OF SELF-MADE POISONS

It being granted that water must enter the body, we find that the mouth alone is a feasible channel. The skin takes up no water when immersed in it, nor does it take in any from the air. The lungs inhale water at every breath, but a moment later they exhale more. The nose cannot be employed, for that is sacred to the passage of air, which is as necessary as water. Thus the mouth alone is to be considered. But the necessity is so absolute that sometimes the mouth, for one reason or another, may not suffice, and then life may be maintained, or imminent death averted, by introducing water into the body in other ways.

The essential is to get the water into the blood. This may be done by getting the body to absorb it when introduced into the lower end of the alimentary canal, or by injecting the water into loose tissue under the skin, say, of the small of the back or elsewhere, or even, in desperately urgent cases, by introducing the water into a vein, opened for the purpose. These last procedures have all lately taken on a quite new importance in medicine, since doctors began to discover what the importance of water in the body really is.

We know that all life is lived in water—nay, more, that it is lived in a stream of flowing water, commonly invisible, but there none the less. In a tree, the stream of water, liquid or gaseous, is, on the whole, from below upwards. In a man, the stream is, on the whole, from above downwards. In both cases it is vital. The stream may be arrested, without the absolute extinction of life, but the vital processes will be suspended. Seeds may be dried without dying, but neither do they live. This is what the French call "vie suspendue," an admirable phrase, expressing the fact that the life is suspended, but may be resumed. Microbes may be maintained for as long as six weeks in frozen air, and recover, but they do not multiply while thus frozen, for their vital processes are all suspended, Similar observations have been made upon fish in frozen water. Frozen air would kill a fish, or one of ourselves; and frozen water would soon kill one of us, who are warm-blooded, as a fish is not. These illustrations suffice to show that life is lived not only in water, but also in liquid and flowing water: we must drink or die. There are fasting men, but not men who go without water.

Though man and tree agree in this respect, the body of man has a very different history from that of the tree. The normal fluid of our bodies is not pure water, but water containing a very small but real percentage of common salt. Probably we should include other salts, but, at any rate, common salt, sodium chloride, is necessary; and water containing the due proportion of it is called "physiological salt solution," or "normal saline." Pure water is never injected into the body for any purpose. Even the doctor who injects a dose of water, instead of morphia, to quiet a patient harmlessly, must add a little salt, for pure water would cause far too much pain and irritation.

When water is injected into the tissues, or into a vein, for any medical purpose, it would never do to use pure water. Similarly, if we are observing the behaviour of a piece of nerve, or a piece of muscle, which has been removed from a freshly killed animal, we must keep the nerve or muscle moist, or it will die at once, but we must not keep it moist with pure water, or it will die very soon. We must supply it with "normal saline," and it may live for many hours, until at last it dies of starvation. If a frog be killed, and the heart removed, and pure water run through it, it will soon go into a state of spasm, and then die, but if supplied with "normal saline" it may beat for a

long time, and teach us facts which we should never otherwise learn.

One of these facts is that the heart requires a sufficiency of fluid inside it, if it is to be stimulated to beat. It likes the grip of something substantial for its muscular fist to grip and squeeze. The chief immediate danger of loss of blood is simply loss of fluid to keep the heart stimulated. In old days men tried to inject blood in cases of hæmorrhage. That is never done nowadays. But lives are saved every day by injecting simply "normal saline," and so persuading the heart to keep going until the body can make new blood and recover itself. This is the best and surest and quickest and most essential of all the "water cures" ever heard of, though unfortunately the least heard of.

Why Parching Comes with Fever and Follows Alcohol

In fever, the body demands more water than ever. The reasons are various. Partly more is needed because more is being lost by perspiration; partly more is needed because water dilutes poisons, and in fever the body is being poisoned. The need of water after taking alcohol is exactly similar. The tongue and mouth and throat are parched because all the available water is needed to dilute the poisons where they are attacking vital organs; and this parching causes distress and interferes with swallowing, and often causes the throat and tongue to become dirty, and add to the general poisoning.

Yet another reason why the patient asks for water in fever is that he is hot, and the addition of cold water to his body will in itself lower his temperature, as it would lower the temperature of anything else. The liberal supply of cool water to the inside of the body in fever has all the advantages of the application of cold water to its outside, and far more. The water bath which may reduce the fever safely, and induce sleep, can have no more than this external and physical action.

The Advantage of Sluicing Out Poisons from the Body

But water within not only cools the body by getting away some of its heat; it deals with the cause of the fever by draining away the poisons which are producing it. Not merely does the water dilute the poisons which are within; it also removes them, which is much more. Doctors argue about the best stimulant of the kidneys and the skin, and discuss the merits of various drugs, but unless these organs are themselves impaired, far and away the best stimulant of their action is water. The passage of water from the body is carefully proportionate to its entry—evidently, as the business of the body is to maintain just the right quantity of water in it, no more and no less. Thus to add water is to expedite the departure of water; and though these processes sound as if they cancelled one another, they do not, for the outgoing water carries poisons away with it, and that makes the vital difference to the balance.

All this is evident once it be thought out; it can be illustrated at any time, it satisfies the mind as theory, it satisfies doctor and patient as practice. Its practice shortens the course of fevers, lowers the death-rate, reduces complications, and promotes the patients' comfort to a degree which only patients know. It obviates the necessity for giving anything like so many drugs, either for sleep, for the reduction of the fever, or for the stimulation of kidneys and skin.

The Popular Fallacy About the Place of Thirst in Disease

We may well find it hard to believe that anything so evidently right is a new thing in medical practice. Until quite recently every symptom of fever was regarded as morbid, and to be repressed and opposed. The truth that you can repress and oppose thirst by satisfying it was not admitted, for the thirst was supposed to be a symptom of the vicious disorganisation of the nervous system. Really, it is a beneficent device of the healing power of Nature, which the few wise have seen in all ages. The medical reformers who instituted the revolution in practice which has now become practically general were, of course, abused and looked upon as dangerous persons, but their patients recovered; nor does it require any very expert eye to see the relief and improvement in a fever patient when he is rationally treated in this respect.

Unfortunately, though it takes a long time for any advance in medical knowledge or common sense to educate the profession in general, it takes still longer to educate the public. The medical ideas of the public are always, in general, two generations out of date, for they are the ideas of the preceding generation of doctors, who, as a whole were a generation behind the best knowledge of their time. This rule about popular medical ideas can be illustrated copiously, but here we merely note its illustration in the case of fever. Anxious

parents and relatives and amateur nurses still incline to alarm whenever the feverish child or other patient snatches at a tumbler of water. After a few sips the tumbler is withdrawn. The thirst is unusual, it is abnormal, it is a symptom, and *therefore* they think it is morbid. It is not: it is an expression of the patient's health asserting itself against the disease, and our business is to help it. We have seen already that a man may, in a just sense, be said to show the real quality of his health never so well as when he is in the grip of pneumonia. Let us now see to it that we distinguish between the symptoms of health and the really morbid symptoms when we are ill. At present our behaviour is foolish beyond words. The patient is thirsty, as he should be, and we deprive him of water. The patient is without appetite, as he should be, and we try to force food upon him.

Every doctor in general practice knows that it is his incessant daily problem to prevent friends from feeding a patient who has no appetite and cannot digest, and needs rest. They fear he will starve, and therefore they poison him. This is in anticipation of a great subject, but we may keep it in mind to "pair off" with the corresponding error about the patient's need of water.

Old-Fashioned Errors About the State of the Air in a Sick-Room

But one word about air in fever, for the two subjects are really one. Everyone is familiar with the drying properties of air, and especially of air in motion. The advantage of the motion is that new portions of air are brought up to carry away their quantum of water, when the former ones are loaded. All this applies equally to us. The amount of water-vapour in the air to which we are exposed affects us closely, much more so if we have fever, for then our best hope of getting cool lies in the loss of water by evaporation from the skin. How much heat may thus be lost we can learn by omitting to dry or dress ourselves after a bath. This simple, if dangerous, lesson will convince us that the evaporation of water from the skin is invaluable when we want to be rid of an undue quantity of heat. If this is to be effected well, the air must be changed.

Here, again, is a simple and satisfactory theory. Yet what, until the other day, was the universal practice, and what is today the all-but-universal practice? The fever patient is kept cosy in a room with a fire, and the windows closed; and perhaps sandbags and what not at every chink. Remember that water is also withheld by the mouth, while its departure from the skin is retarded by the enclosure of the air, which soon becomes practically as full of water as it can hold. Only one other thing is required to complete the patient's discomfort, maintain his temperature, and guarantee a good-going headache and an uneasy night. That something is an excessive supply of blankets, and it never fails to be forthcoming. The patient requires, in order to combat his enemies, to produce extra quantities of heat.

How the Best Modern Doctors have Revolutionised Air Treatment

If this is to be done with safety, he further requires to be rid of them, so that they shall not mount up to danger point for his nervous system. We deprive him of water internally, with its double function of draining away heat and draining away the poison which makes the production of so much heat necessary; we pile blankets on him, and we interfere with the change of air, so that the loss from his surface of what water he can spare under our mishandling of him is sadly interfered with.

The best modern doctors have revolutionised all this. No trace of it is to be found in a first-class fever hospital, in the wards of a general hospital containing such fever cases as pneumonia, nor in the sanatoria which are devoted to the special kind of fever produced by consumption. The precious stream of water is freely allowed to flow through the patient. This process is aided by the open windows, or actual open air which surrounds the patient, and he is lightly clad, for decency and the comfort of the nerves of his skin.

Wrong and Dangerous Notions as to the Origin of Fevers

Under such conditions, to mention nothing else, fever has lost half its terrors, the death-rate has fallen enormously, and the period of convalescence has been reduced by days or weeks on the average. None of this is "water-cure" or "hydrotherapy" in the ordinary sense of the words, but this is what the ordinary sense of the words should really convey. It is the natural, simple water-cure, applied to a being which can only maintain its life at all under a sufficiency of such conditions.

Before we see how these new facts regarding disease bear upon health and the minor forms of ill-health, let us just observe what was the idea at the root of all the disastrous practice of the past, and the present. It was the idea that fever is typically due to

cold. Heat and cold must be discussed when we come to clothing, but meanwhile we must note that, though cold may be harmful and fatal, it does not do one tithe of the harm we suppose. A "cold in the head," or pneumonia or laryngitis or bronchitis—these are due to microbes. The microbes cause the fever, and the fever must be understood if it is not to be maltreated. We associate fever with cold; therefore we tremble when we see the fever-patient drink cold water, we are terrified at draughts, and we pile up the clothes.

The Advantages and Disadvantages of Moisture in the Sick-Room

Even if it be true that cold originally caused the illness by lowering the temperature *below* normal, and so lowering vital resistance to microbes, that does not mean that we are now to fear cold when the patient's temperature is *above* normal. The point is clear when it is made, but there has been too little of "fundamental thinking," even the most elementary, in such matters.

It is plain that what we have argued about the moisture of the air must be considered when we have a steam-kettle in the room. Here, again, we require to discriminate. The steam-kettle, by moistening too dry air, often relieves a cough due to dryness of the air-passages—from whatever cause—as nothing else can. It has relieved and brought sleep and recovery to countless patients.

But it has probably killed as many more, by filling the air with moisture when the patient's lungs were water-logged, and when what he needed, above all, was a dry air, quickly moving, to carry away the moisture from his lungs, and save him from this cruel form of death by drowning. Unfortunately, there is a cough, alike when the lungs are too dry and when they are too wet; and so, too often, the steam-kettle has been turned on to drown the drowning patient, because at other times it has been found to relieve the parched patient.

The Importance of the Circulation of Water Through Our System

Now, let us consider our own case, in health, or some imperfect imitation of it. We notice, very often, that what we call our "form" or "fitness" varies with the weather. We have headache and irritability, and cannot work, before a thunderstorm, and we feel better after it, when the rain has come down and the air is clear. What do such things mean?

Probably they depend on just this question of the flow of water through the body. When the air is humid, this flow is retarded. When the rain has fallen, and the air is fresh and clear, it really is far less humid than before, and therefore we can more readily lose water to it. In short, such air promotes the circulation of water. This is not the key to all questions of climate, the weather, and health in such varying conditions, but it is probably one of the most important of all facts in this connection, and it is of equal importance to all of us everywhere, for the circulation of water through the body is one of the necessary facts of all our lives. We now know that half the ill-effects of bad ventilation are due to the mere moistness of the air, which it has derived from the breath and skin of the persons inhabiting it. And the action of the moisture wholly depends upon retarding our further loss of moisture.

The Incomparable Cleansing Agent of which We are So Suspicious

How much this bears on health, and how clearly it leads to a new maxim for health—that nearly all of us drink far too little—we can only realise if we remember that everything living, in the course of its life, produces poisons. This is a necessity, and there are no exceptions to it. Plants produce poisons, and get rid of them by their roots and otherwise. Animals, which are far more active, produce far more. It may almost be said that the healthiest man is he who best rids himself of his poisons. To have a good skin, a good heart, good lungs, good digestion, and so forth—all these mean, at least as much as anything else, good riddance of poisons, or good destruction of them within the body—which also happens. Water is the incomparable cleansing agent, for the whole of this process is to be looked upon as cleansing. Cleanliness is next to godliness, we say; it is certainly necessary to godliness, for if internal cleanliness falls below a certain point, we cease to display any virtues or vices any more.

All this is an old story, as well as a quite new one—so new as to startle and offend hosts of good people, who, nevertheless, remember and act, and are ever after better therefor. The association between religion and health has always been close, and many religions are largely codes of hygienic morals. But nowhere is this association so close as in the Jewish and Christian religions; and there is no principle of health now established by science which may not be found expressed, doubtless with Oriental

imagery, but none the less clearly, in the New Testament. In matters of mere physical health, to say nothing of higher things, we may all do well to recall such words as: "Woe unto you, scribes and Pharisees, hypocrites; for ye make clean the outside of the cup and platter . . . cleanse first that which is within the cup and platter, that the outside of them may be clean also. . . . Ye are like unto whited sepulchres, which indeed appear beautiful outward, but are within full of dead men's bones, and of all uncleanness."

Such words have a clear enough illustration in the case of those who are careless about internal cleanliness, and whose lack of it leads to anæmia and its pallor, but the language is so strong that the reader may make the application of "whited sepulchres" for himself. The pity is that such people may be scrupulous, personally—as we say, highly fastidious—and spotlessly clean. But it is only to the outside of the cup and platter that they attend.

More astonishing still, in its closeness to the most recent findings of science, is the following: "Not that which goeth into the mouth defileth a man, but that which cometh out of the mouth; this defileth a man."

The Real Poisons in Our Bodies are not Put There, but are Made There

Just thus does science now teach. In our food there are poisons, no doubt. The stomach and the liver usually deal with them, and they do not defile us. The poisons that constantly matter, and from the action of which we are never more than one stage removed, are those which proceed "out of the heart"—that is to say, which are made by the very life, the ultimate living cells of the body, cells of the heart and the brain, and the glands and the muscles, and all others. These are the poisons which defile, these are the real dirt, and these it is which we must be rid of if we are to be clean. One of the modern discoveries regarding old age is that there is a widespread imitation of old age, which is not old age at all, though we call it so, but which is really the result of slow chronic poisoning, day by day, for years, accumulating more than the organs of excretion can dispose of. It is, of course, a grave discovery; and all our ideas of cleanliness and of the use of water require revision accordingly. First and foremost for each of us, whether we attend to it or not, is the cleanliness of things not seen, which only the flow of the cleansing stream of water through the body can maintain. If this cleanliness fails, the results are *instantaneous*. If, at this instant, the reader could be so placed that no water left his skin, none left his lungs, and none was abstracted from his blood by his kidneys—a process which never ceases, day or night—he would instantly begin to suffer in his head; would fail in the effort, perhaps not too arduous, of concentrating his attention on these words, and in a few hours, certainly, he would be dead. Now, all stages between cessation of life and merely feeling dull or sleepy at a theatre, or in church, are possible in consequence of inadequate internal cleanliness; that is, as regards immediate results. Similarly, as regards chronic results, they may vary from a mere diminution of efficiency and fitness day by day, up to a degeneration of all the organs of the body, and premature death from apoplexy, or many other maladies, really due to chronic auto-intoxication, or self-poisoning.

The Laws of Health that Teach Us How to Drain Away Inward Poisons

The laws of health may thus be said to be "writ in water," but in this case the writing remains, and we must obey it. We find that it is largely these laws which we are obeying when we profit by exercise which makes us perspire. We find that the doctor who somehow persuades his patient to perspire freely may save his life. The critic will not be so foolish as to quote the "night sweats" of consumption, for the doctor rightly tries to arrest them, not by preventing the sweating from without, but by arresting the causes of self-poisoning which the sweating is an attempt to counteract. Alike in health and in disease, we have a new understanding of perspiration, as being not merely a means of regulating the temperature mechanically, but as also a means of drainage. We shall similarly look upon all the modes in which moisture leaves the body, if we care about cleanliness, as we never did before.

The Wisdom of Accommodating Ourselves in Our Exertions to the State of the Weather

Further advice for health flows naturally from this principle. We shall not try to get the utmost from ourselves when the atmosphere is very humid. Such are the times for rest or very light work, as everyone knows, in parts of the world where the difference between humid and dry states of the air is marked, and where they rapidly alternate. Even in our climate it is worth while to recognise the difference.

Further, we shall avoid whatever adds unduly to the humidity of the air, and thus interferes with our personal drainage, and threatens to lead to self-poisoning. This means, above all, that we shall promote good ventilation, for good ventilation means good personal drainage, free flow of water, from skin and breath in especial, and good riddance of much bad rubbish.

Further, we must carefully attend to the supply of this essential fluid, and, though this sounds easy, difficulties arise. We cannot store in the body, either before use or after use, any quantities of water worth mentioning, and thus the intake must be frequent. Water, like all fluids, is incompressible, which means that it always takes up in the body just as much room as it did outside, or more, for now it is warmer. It cannot be tightly packed away anywhere; and it is heavy, and interferes with movement, as anyone knows who has drunk too liberally during a game of cricket or tennis, or before a race. This interference with movement may be very serious, and is never to be forgotten, because any fluid—and most fluids are mostly water—in the stomach is near the heart, which lies over the stomach, and the heart has to expand, while this incompressible fluid is just outside it.

The Pleasantest Form in which Water Can Be Taken is in the Juices of Fruits

Men have often died from sheer mechanical interference with the heart in this fashion, when seeing how much they could drink for a wager.

Such men could, perhaps, be spared, but they point a moral for people whose hearts are delicate or are being heavily taxed. Our supply of water to ourselves should tend towards "little and often," rather than seldom and much; and this applies much more to ill people, whose hearts are being poisoned and must be considered. In the interests of the heart itself, such people must get all the water they require—not necessarily all they ask for—but they must get it in small frequent doses. This is the problem of nursing; for if you leave the patient a full tumbler, he may drink it too quickly, and if you only leave him as much as he should take at a time, you must be prepared for the trouble of body and of memory involved in keeping his little cup replenished. That is the difficulty; and those who care for nursing, or who have nursing duties thrust upon them, should understand it.

Most of our food is moist; much of it, not ranked as fluid, consists of water to as much as 70, 80, or 90 per cent. of its weight. Thus one may take abundance of water without ever exactly drinking any, and this is especially true of those wise people who consume large quantities of fruit. Not only do they get plenty of water, but they get it in pleasant and safe form, and with the addition of acids and salts which make it fitter than ever to act in cleansing the body. The acids and salts of such water help it as the soap helps water outside the body; they are the soap of internal washing.

A Word of Warning on Overdoing the Taking of Essential Water

We cannot yet involve ourselves with the huge question of diet, but we must praise fruit here; and we must also remember that water, even the water in fruit and vegetables, is not food in the ordinary sense of the word, and that of course it must not be allowed to interfere with the taking of food. It is apt to do so. It occupies space, and space in the stomach is limited. If we take too much food and water, the stomach has no choice but to dilate, which is a disaster. Further, water dilutes the digestive juices of the stomach, and cold water lowers the temperature of the stomach, and thus interferes with the digestion in two ways, for no food can be digested except at the temperature of the body, and none of the digestive ferments can work if they be too much diluted. Besides, if the food be too much diluted with water, the stomach wall does not respond to it, and the digestive juices are not even produced in the first place. For all these reasons it is certainly not good to drink too much with one's meals; and there are many forms and stages of illness in which it is better to have one's meals as dry as possible, so that they reach the stomach moistened only with saliva, and may be digested well, as they would not otherwise be.

When to Drink with Best Advantage and How Much to Drink

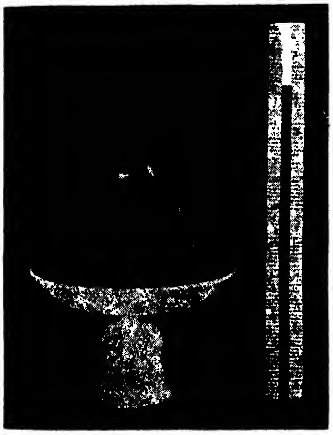
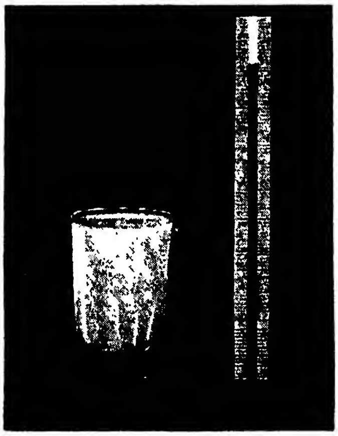
The rule, therefore, is that, if one adds fluids to a substantial meal, they should come at the end or near it. The first call to the stomach should be made by food that has plenty of flavour to which the digestive juices respond—not by insipid food, as too much water would make it. Thus the knowing cook gives us, at the beginning of a heavy—probably much too heavy—dinner a small quantity of very highly flavoured and concentrated soup, and practically no one feels inclined to dilute it freely with water. If the digestion is at all dubious we should be careful about drinking with meals. The

time for fluids is after meals, and, better still perhaps, between them. Many people recognise this in the middle of the morning, in the drink at bedtime—an excellent practice—and in a light afternoon tea.

The temperature of the water one drinks, either as water or as the essential part of some beverage, does not much matter in health, though naturally the fever patient likes to sip cold water or suck ice, and though the person of weak digestion should avoid cold drinks, certainly cold drinks with meals, for the reasons given. Much argument still proceeds as to hot versus cold drinks; and it is probable that this is largely one of those cases where we vary by nature or habit, and where every man should learn to be his own physician. If the skin is not acting well enough, a hot drink may often stimulate it, and so, in the long run, cool one more than a cold drink would have done. But if perspiration be already free, a cold drink will cool one more than a hot. Again, to many people the heart becomes slack during great external heat, and they promptly feel revived when a cup of hot tea has been lodged beside the heart and has stirred it to better efforts. Such people swear by hot drinks in hot weather. Other people, whose hearts do not get slack at such times, cannot understand this preference, and plump for iced drinks. Both parties, of course, think each other peculiar and absurd, and even try to convert each other. Fierce controversy similarly rages, even in scientific quarters, with abundance of dogmatic conclusions, naturally opposed, because the variety and complexity of the body is forgotten, and all men are supposed to react similarly to hot weather, and similarly to hot or cold fluids.

Here, therefore, no advice of the dogmatic kind will be given. The writer loves ices, and takes iced drinks copiously all through the summer, and knows they are good for him, and knows why. If he were to recommend to everybody what suits him so well, he would be simply foolish, but in abundant company. People must find out for themselves what is best for them; and the best service of these pages is to guide their search as far as possible.

The question of beverages is not for present consideration. It suffices now to accept the modern evidence which suggests that we should most of us do better to live in a somewhat less sluggish stream of water than we are content with. We do not take in enough, and we do not get rid of it fast enough. Thus our life is lived in water which is certainly not stagnant, for that we could not survive, but tends to become so; and we suffer as cut flowers suffer when they are allowed to be poisoned by their own products, because no one changes their water often enough. We must take more exercise, not in order to become marvels of physical development, but in order to keep flowing the stream of water in which we live; and we must frequently replenish that stream, not least at the beginning of the day, when we have so long been without a fresh supply, and at the end of it, when we ha[illegible]many hours without drinking in front of us. If the body could speak, and not least if the nervous system could speak, on its own behalf, one of its favourite phrases in modern life would be "It is long between drinks." Adam's ale was the amœba's, and will be the superman's, too; and every living thing is, first and last and all the time, a water-drinker.


THE PROPORTION OF WATER THAT IS IN APPLES, MILK, AND A LOAF OF BREAD.
The measure beside each of these pictures shows by the dark line the percentage of water in each

LIGHT PASSING THROUGH THE MICROSCOPE

This sectional drawing of the microscope shows how the light falls on the reflecting glass, passing through the condenser to the object on the slide-rest, and thence through the lenses to the eye.

SEEING THE INVISIBLE

How the Microscope Magnifies Man's Sense of Vision and Reveals a New World of Life and Movement

THE CHIEF INSTRUMENT OF MODERN SCIENCE

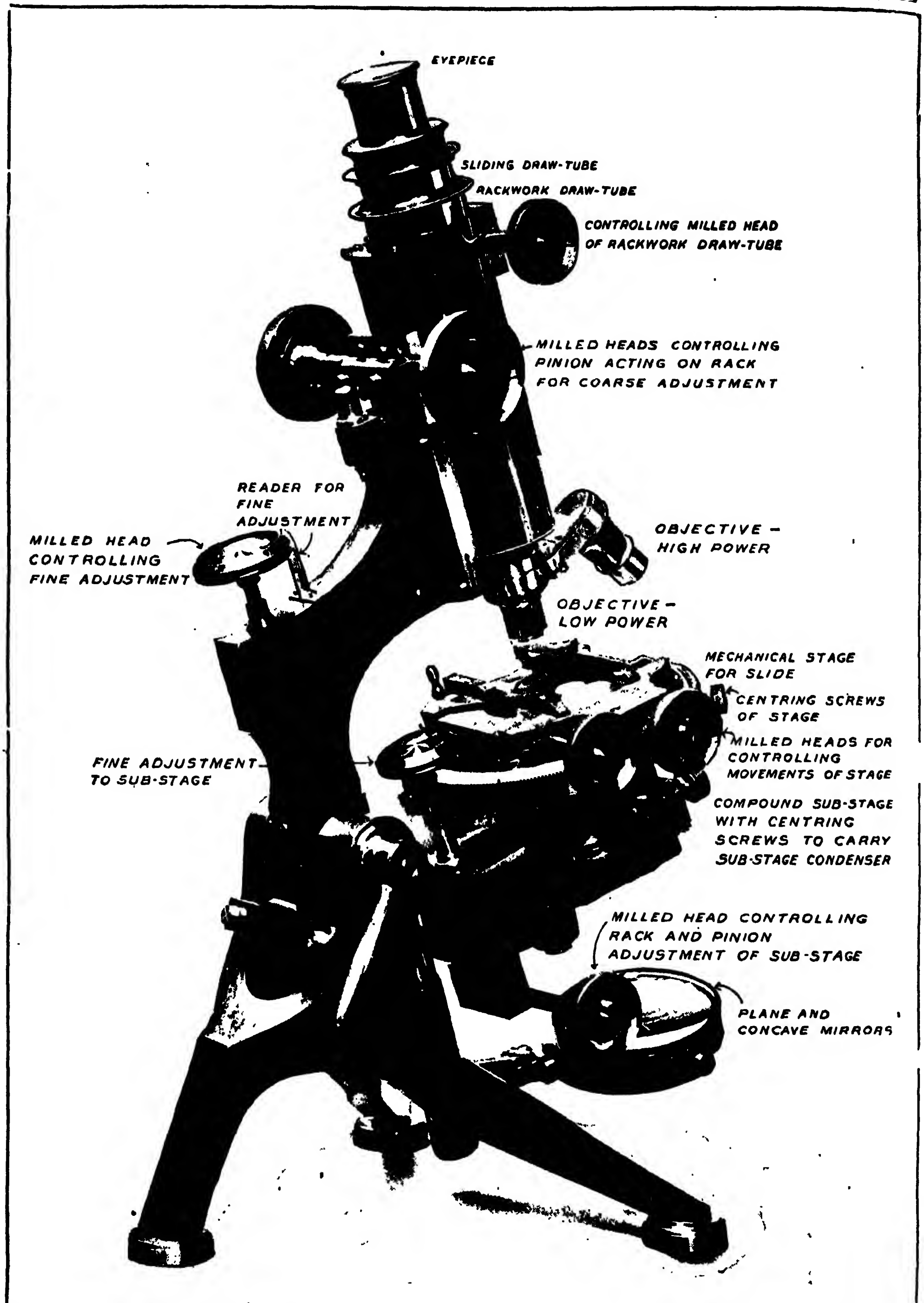
Of all the instruments of modern science the microscope is the chief. There is nothing to be compared with it in the range, the importance, and the diversity of its uses. The arts of working metals are now being perfected by its extraordinary powers of vision; and in many of our principal manufactures, such as textiles, the microscope is becoming indispensable. It is by means of this wonderful little instrument that the white race is obtaining control of the tropics, and establishing its civilisation there; the secret armies of disease are being rapidly vanquished by it; without it, our knowledge of the wonders and problems of life would remain childish.

By means of the microscope, objects about a quarter of a millionth of an inch in size can be distinguished from each other and photographed. By the ultra-microscope still more minute things are made visible—one-sixth of one-millionth of an inch is the present limit—and when the ultra-microscope is used with a cinematograph apparatus, we are able to record the motion of infinitesimal forms of life or energy which have hitherto been invisible.

The microscope is a window opening on a new, inspiring, and glorious universe. Discovered in its modern form a few years after the telescope, it enables man to recover the sense of the dignity of life of which the telescope robs him. Pointed at the midnight skies, the telescope seems at times to proclaim that human life is mockery. It exhibits our world as an insignificant planet spinning round an insignificant star—as a tiny speck in an ocean of space and matter, peopled by a race of puny creatures who style themselves lords of creation, although their dominion does not extend over a billionth part of the universe. Everything around us shrivels up in the light thrown on it by the telescope, which enables the astronomer to think as easily and as quickly in millions of miles as the ordinary man thinks in inches. Mere size, mere space, becomes an obsession; the fine, true, living feeling for quality is lost in a nightmare of hugeness and spaciousness.

We look out into a ghastly, illimitable desert, strewn with whirling lumps of fiery stuff and cindery ruin, held in various groupings by mechanical force. It is a sight to make us dizzy and to appal the strongest soul. "The infinite spaces of the universe frighten me," said Pascal, one of the most daring of French thinkers; and Herbert Spencer, towards the close of his life, said the same thing in almost the same words. There is a horrible simplicity in the view that we get through a telescope. Everything that ennobles, that produces variety, interest, mystery, seems to be wanting. The immensity is sublime, but with an inhuman sublimity—a vast spectacle of meaningless combinations and manifestations of electric energy. If we accept it, just as we actually see it, with no sign of life apparent, it becomes a vision of terror—of annihilation—from which nothing can finally escape.

Faith and courage, however, can save us; courage born of our inner sense of the worth of the spirit, and faith born of the mysteries of life now revealed by the microscope. The microscope shows us that a speck of matter, so small that it cannot yet be measured, may be more sublime, more wonderfully formed, more mysterious and awful than the entire universe of millions on millions of suns perceived through the telescope. For in the speck of matter is life. Thus we regain our sense of the superiority of quality to quantity. Life may be a miracle or a progress, but it is certainly something higher than the play



The microscope, the chief instrument of modern science, by showing the unimportance of size, has brought back the dignity robbed from man by the telescope.

For this descriptive photograph of a fine modern microscope, and for many pictures in these pages, Popular Science is indebted to Messrs. W. Watson & Sons, the famous microscopic instrument makers. The splendid photograph from a meteorite, on page 966, was taken through a powerful Leitz instrument; and other photographs are by Mr. J. J. Ward. Messrs. Hinkins & Son. and Mr. W. Tams

of mechanical forces in large masses of flaming or charred dirt, which is all the telescope can show us when it sweeps the skies. Life may be destined to fail from the universe, or to spread through it and give it meaning and value. However this may be, it is incontestable that the microscope makes a clot of our earth richer in marvels and interests than the Milky Way.

We can perceive in a small piece of earth or in a drop of water extraordinarily minute vegetables belonging to a new and mysterious kingdom of life, and possessing every external attribute of an animal, such as the power of moving about and the power of feeding on other forms of life. We are able to trace in particles of matter, visible only by the ultra-microscope, strange motions, like those of a swarm of dancing gnats, hopping and jumping about together, and flying apart with astonishing rapidity; and in other varieties of matter we can distinguish strange processes of growth, which make some men of science think they are about to solve the problem of the origin of life.

THE SCALES IN A SPECK OF DUST FROM THE WING OF A MOTH

But the microscope humbles the pride of the human intellect, while extending the power of human vision. It penetrates beneath every simple surface of things to an underlying complexity, strange, marvellous, and awe-inspiring. When the microscope was still very imperfect, Huxley and Tyndall thought they discovered the secret of life in protoplasm, but a few improvements in the manufacture of glass for microscopic lenses led to the discovery that there was much more in the simplest of cells than protoplasm, and, moreover, showed what complicated processes take place within the simplest cell. At each magnification of our powers of sight, the mystery of life grows still more mysterious. That is why microscopic science is so alluring. The field of knowledge is immeasurable. Take just one

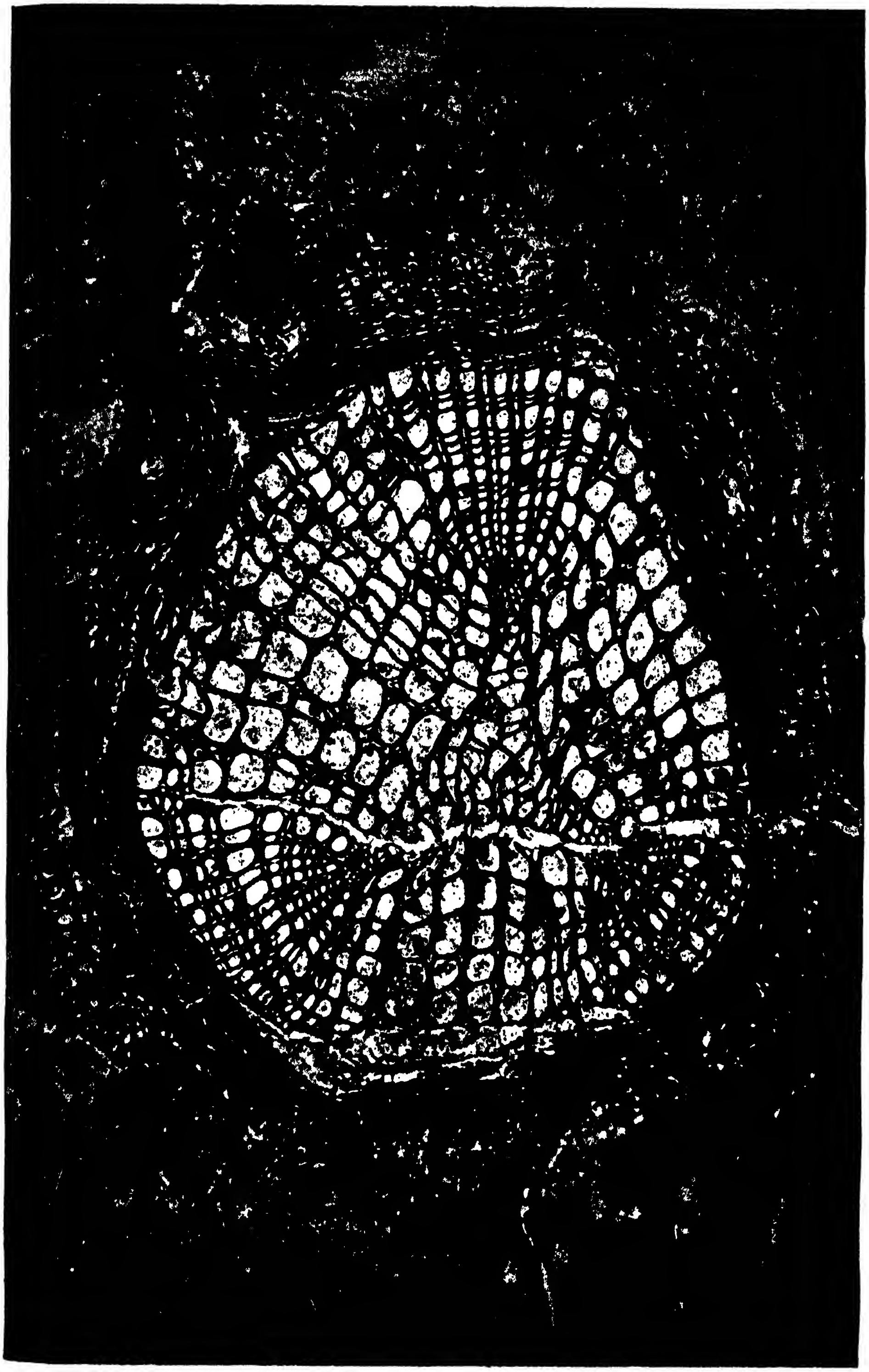
corner of it—microbe study; scarcely a thousandth part of the work required to be done there has yet been performed, so complicated, so varied, so enigmatical are the tiny shapes of life whose territory we are beginning to explore.

THE HEAD AND SHOULDERS OF THE COMMON FLEA

The modern microscope is one of the newest instruments of science. The true principles of it were not generally known by actual experiment until about 1881, when a German mathematician, Professor E. Abbe, induced a German glass-maker, Dr. Schott, to work with him in manufacturing a new kind of lens. Abbe, who had been studying the problem of optics since 1873, overthrew many of the theories of the microscope formed by his predecessors. He discovered what a microscope could be made to do, and he made it do it. He fixed the uttermost limits of vision of the marvellous artificial eye, and the last instruments constructed in accordance with his ideas seem now to have reached those limits.

Abbe was considerably indebted, in his splendid researches, to various British men of science, who worked out some of the chief laws of the microsccpe; and, since he completed his work, several of our country-

A COAL-MAKING PLANT MAGNIFIED



We see here a transverse section of the petrified stem of a fossil plant taken from the coal measures, and showing clearly, when magnified seventy times, the central core of wood and the ring of bark.

men have effected important improvements. Lately, Sir Almroth Wright has contested the validity of Abbe's views in regard to the limits of microscopic power. He holds that Abbe was mistaken in one of his principal theories; and he states that a mass of evidence, accumulated by trustworthy microscopic observers, goes to show that objects have already been clearly seen lying beyond the supposed limit of the microscope. If this is so, there is opened up the prospect of an advance in microscopy which will have a profound influence on many important branches of science.

The Punishment of the First Great English Man of Science for Being Before His Time

So far as is known, the original invention of the microscope is due to Roger Bacon, the first, as well as one of the greatest and most unfortunate, of English men of science. Bacon was a Franciscan monk of Ilchester; and in 1276 he presented his "Great Work" to Pope Clement IV., in the vain hope of obtaining authority to go on with his researches into the mysteries of Nature. In the course of his book, Bacon showed how crystal lenses could be used to make objects appear larger. With these lenses, said Bacon, there could be made "an instrument useful to old men, and to those whose sight is weakened, for by means of it they would be able to see letters, however small they are, made large and clear." Men who found out things like this in the thirteenth century must, it was generally thought, have gone to the devil for help; so Roger Bacon was kept in prison, and all progress in science was stayed for three hundred years in England.

To save them from destruction, Bacon's writings had to be hidden; and, though his "Great Work" seems to have been read by at least one man in the sixteenth century, it was not generally known until it was rediscovered in 1733. By this time the compound microscope had been in use for a hundred years; yet the germ of it can be traced back to the English monk, with a break of only four years.

The Spectacles which were Unknown to Mankind 600 Years Ago

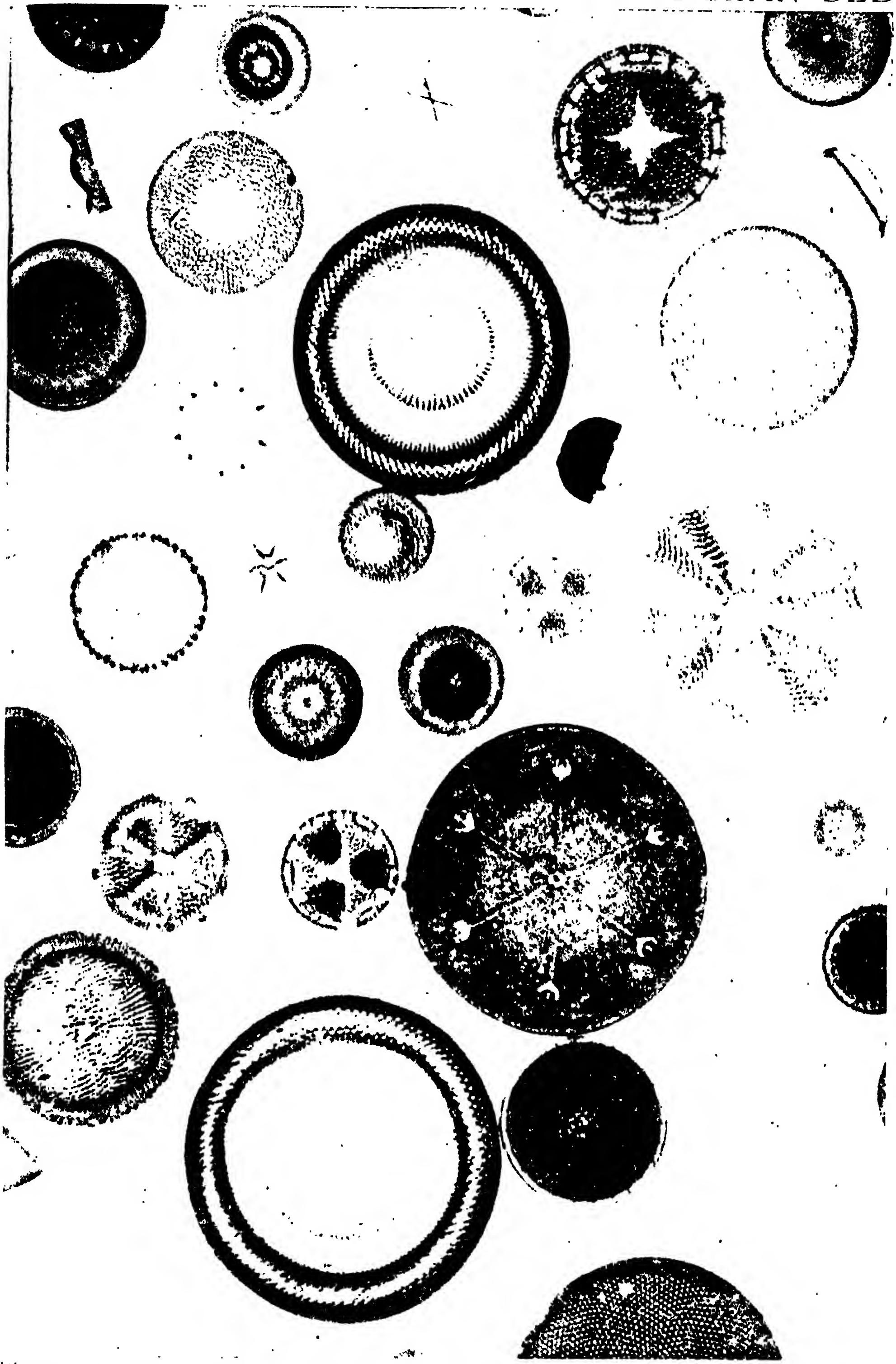
In 1276, as we have said, the "Great Work" was presented to Pope Clement; in 1280, an Italian, Salvino degli Armati, of Florence, brought out a pair of magic glasses in accordance with Bacon's description. The magic glasses were—a pair of spectacles! This is now the commonest form of the simple microscope—two magnifying lenses fitted in a frame so as to be used before the eyes. Is it not extraordinary that so apparently commonplace an aid to failing sight should have been unknown to mankind six hundred years ago? In a former chapter of this book (page 198) we referred to the famous Nineveh crystal as a possible anticipation of the use of the simple microscope or magnifying lens. In so doing we only followed some of the best authorities. In the eleventh edition of the "Encyclopædia Britannica," for instance, the Nineveh crystal is adduced as the earliest extant example of a magnifying glass. It is about two thousand six hundred years old, and it consists of a piece of rock crystal, oval in shape, and convex on one side.

On carefully examining the crystal at the British Museum, we find, however, that it is only an ornamental stone, used probably as a Royal jewel. There are cloudy streaks in it, which enhance its value as a decorative object, but are absolutely fatal to its optical qualities. Moreover, it has not the smooth surface necessary in a magnifying glass; it is ground in facets like a diamond, and this is further proof of its merely ornamental design.

Men who Saw the Way to Further Knowledge, Standing on Roger Bacon's Shoulders

Magnifying glasses were unknown to the Greeks and the Romans; and all the evidence adduced to the contrary is, we find on going thoroughly into the matter, as baseless as that of the Nineveh jewel. On the other hand, the Arabians of the eleventh century seem to have known something about the optical qualities of convex crystals; and it was possibly from them that Roger Bacon obtained the ideas which he developed into the principles of the microscope and the telescope. The Italians who read the "Great Work" of Roger Bacon were practical men with narrow views. Like many other inventors, they could apply in a useful way a principle worked out by a greater mind, but they could not develop the principle. For more than three hundred years after the simple microscope was made into a pair of spectacles, no advance of importance was effected. It is said that another Englishman, Leonard Digges, chancing early in the sixteenth century to read the work of Roger Bacon, constructed a really scientific instrument, by placing, in accordance with Bacon's directions, one lens behind another in a long tube. Digges, however, regarded the double-lens instrument merely as an interesting toy, owing probably to the fact that the glasses he used were badly ground.

DUST-SHELLS THAT LIE IN THE OCEAN BED



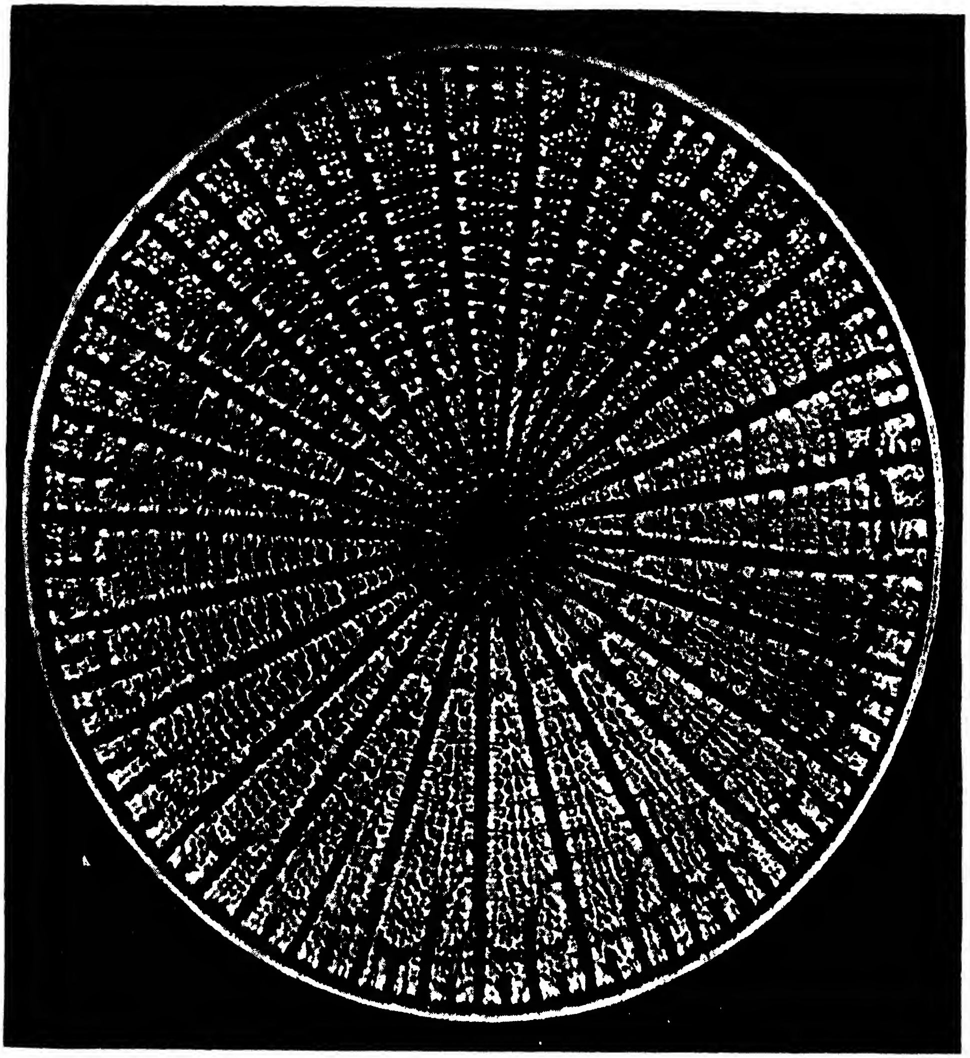
Diatoms are minute sea-plants, consisting of protoplasm with a shell-disc on each side of it, found in immense numbers in the sea, but so small that here they have been magnified 60,000 times.

A FRAGMENT FROM THE SKIES UNDER THE MICROSCOPE—A HIGHLY MAGNIFIED PORTION OF A METEORITE

It was left either to Hans and Zacharias Janssen, spectacle-makers of Middleburg, in Holland, or to Galileo, the famous Italian astronomer, to arm men of science with the most important means of scientific research. The Janssens undoubtedly invented the first telescope; and it is claimed for them that by a simple modification they produced also the compound microscope in 1590, twenty years before Galileo did the same thing.

Instead of vainly attempting to decide this obscure dispute, let us try to obtain an idea of the wonderful achievement itself. In its simplest form the microscope is an artificial lens, acting in the same way as the crystalline lens of the eye. As is now well known, the path of a ray of light is affected by the density of the transparent medium through which it passes. A simple experiment will show this. Fill a tumbler full of water, which is denser than air, and put an ordinary long lead pencil into it, and look sideways at the pencil as it rests partly on the edge of the glass and partly in the water. The part of the pencil which rests in the water will seem to be broken off from the part that remains above in the air.

What happens is this: the rays of light, by means of which we see the pencil, are bent inwards when they enter the water. If we took a little glass globe and filled it with water, and then sealed it up, the water would bend all the rays of light that entered it. The rays would all be bent inwards, and meet together at a certain point. Seneca, the tutor of the infamous Roman



THE MARVEL OF INVISIBLE ARCHITECTURE—A DIATOM, OR WATER-PLANT, MAGNIFIED FROM THE SIZE OF A PIN-POINT

Emperor Nero, noticed that if a globe of glass was filled with water and placed on a written page, the letters would appear much larger than they really were; but all that the Roman philosopher concluded from this was that when objects are seen through water they appear larger than they are. No man in Europe, until the days of Roger Bacon, tried to understand why a globe full of water should magnify the objects behind it. It is from this search into the causes of natural phenomena that modern science was born.

All that was required to discover the principle of magnifying glasses, spectacles, telescopes, and microscopes was the knowledge that the curved surface of a globe of glass and water bends inwards a ray of light, for the reason that glass and water form a denser medium than air. When this was found out, it was fairly easy to begin experimenting with various kinds of glass with various surfaces. This was done by some of the earliest spectacle-makers. They discovered that a convex surface, in which the smooth glass bulged outward, bent the rays of light *inwards;* while a concave surface, in which the glass bulged inwards, forming a sort of saucer-like hollow, bent the rays *outwards*. By this means they worked out in practice a series of convex spectacle glasses for people suffering from long sight, and a series of

THE TONGUE OF A CRICKET

THE FOOT OF A MOLE CRICKET

ANTENNÆ OF A COCKCHAFER

THE STING OF A WASP

concave spectacle glasses which remedied the defects of short sight.

We are in the happy position of understanding more about the matter than the Italians who amazed Europe in the thirteenth century by their magic glasses which improved the human sight, for we know more about the human eye than the old spectacle-makers. A principal thing in the human eye is the crystalline lens. It is composed of perfectly transparent fibres, and has two rounded or convex surfaces like an ordinary magnifying-glass. At some distance behind the lens is a transparent film of very sensitive nerves. This is the retina. It forms a screen at the back of the cavity of the eyeball, and it is coated behind with a very dark coloured matter.

Now, suppose we are looking at this page. The page is flooded with light: it reflects this light, in somewhat the same way as a mirror does. The rays of reflected light spread out, and a certain number of them enter the pupils of our eyes. For convenience let us examine what takes place in the lens of one eye. As this lens has a convex surface, it bends the rays of light inwards, bunching them together. The page at which we are looking is, of course, much larger than the little dark screen at the back of our eye, but the rays of light are so bunched together in passing through the lens that when they strike on the dark screen they form a much-reduced image of the page. In other words, there is printed on the dark screen at the back of our eye a miniature picture of this page.

Thus the eye is a microscope, and attached to it is an exquisite piece of mechanism by which it is adjusted. Around the window or pupil of the eye is a kind of coloured curtain—grey, brown, black, or blue; this contracts and partly closes the window when the light is too strong, and expands and leaves a large opening when the light is weak. More important, from our present point of view, is the muscle of the eye, which is called the ciliary muscle. It presses on the top and on the bottom of the lens. In practically all perfect eyes the lens is flatter in front than behind. But when we look at very near things this flattish front is useless. We need a more microscopic vision, and the ciliary muscle at once gives us this, without any conscious effort on our part. The muscle contracts, and allows the lens to bulge out slightly in front and form a convex surface, like the surface of a magnifying-glass. Our eye

instantly acquires a stronger magnifying power, the rays of light are brought to the proper point at the back of the eyeball, and a clear image is formed of the object near at hand.

Often, when persons are growing old, the lenses of their eyes grow too flat in front; so they have to use a pair of spectacles with convex glasses when they want to see very near objects. On the other hand, people who are constantly poring over books, or using their eyes in other ways for the study of minute objects, suffer from the opposite defect. Their natural vision is excellent at a very short distance, just like a very convex magnifying-glass. Their eyes, however, cannot bring to a point the rays of light from distant objects; so a very indistinct and misty image of these objects is formed on the screen at the back of the eyeball. If we look at the glasses worn by short-sighted persons we shall find that they are hollowed out, or concave. The concave surface bends outwards all the rays of light that pass through them; it makes them diverge, and thus corrects the too convex surface of the lens of the eye, and helps to bring the rays to the proper focus.

The word "focus" meant originally a fireplace. If a magnifying-glass be held in a strong sunlight, it will bend the rays of light and make them meet in a small circle a little distance away from the back of the lens. The spot at which the rays meet will actually become a fireplace if a piece of paper or other inflammable material is held there. When the glass is used only for magnifying purposes, the focus is at the spot at which the rays bent by the glass meet and form a little picture of the object. This little picture is called the image. In the earliest and simplest of compound microscopes, a magnifying glass was inserted at the end of a tube, and the tube was six feet long. Another lens was inserted at the opposite end to serve as an eyepiece.

When the microscope was pointed at a small object, the first magnifying glass collected the rays of light, and bent them, and sent them through the tube in a kind of narrowing stream of rays. All the rays met at the focus, and created an image in a certain part of the tube; and if a piece of paper had been put there, the image could have been seen. Nothing, however, was placed at the spot where the rays met, so they crossed each other, and diverged again in a broadening stream. In this way they carried the image to the second

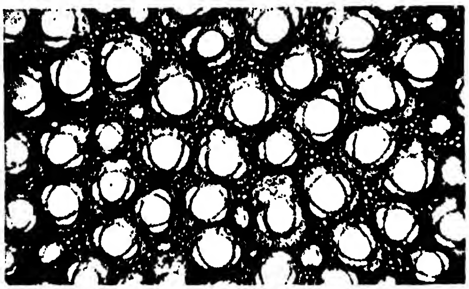
THE MOUTH OF A TADPOLE

LANCES OF A BLOW-FLY

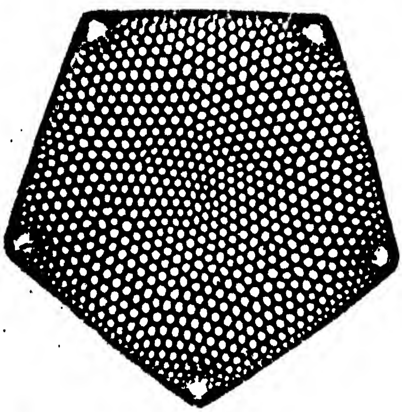
THE CLAW OF A MOLE CRICKET

THE FOOT OF A WATER-BEETLE

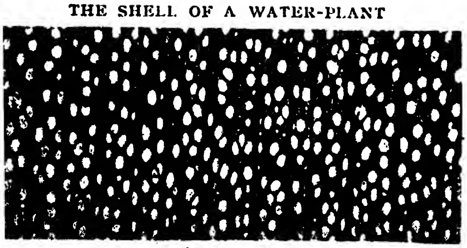
SECTION OF A CLOVER STEM



SECTION OF A PIECE OF CANE



THE SHELL OF A WATER-PLANT



A SECTION OF APPLE-TREE WOOD

lens, or eyepiece. This was also a magnifying glass, and it collected the broadening stream of rays, and again bent them and sent them towards the eye of the observer. Thus there were two processes of magnification.

Such were the most primitive of compound microscopes; and the principle on which they were built is practically the same as that employed in the most powerful of modern instruments. There are two systems of lenses. One is placed at that end of the tube which is directed on to the object that is to be examined. This system of lenses is called the objective. At the other end of the tube, where the eye of the observer is placed, is a second set of lenses, which is termed the eyepiece. The objective is the most expensive and the most powerful part of the microscope. It costs as much as £25, and about six objectives are required with a first-rate microscope. The objectives are detachable, and of varying powers and properties, and their use depends on the kind of work that is wanted, and the kind of object that is being studied. The objective collects the rays of light which come from an object; it bends these rays inward, and sends them in a narrowing stream through the tube to the spot where they form an image. Here they again part and travel to the eyepiece, where the image is still further magnified, and transmitted to the eye of the observer.

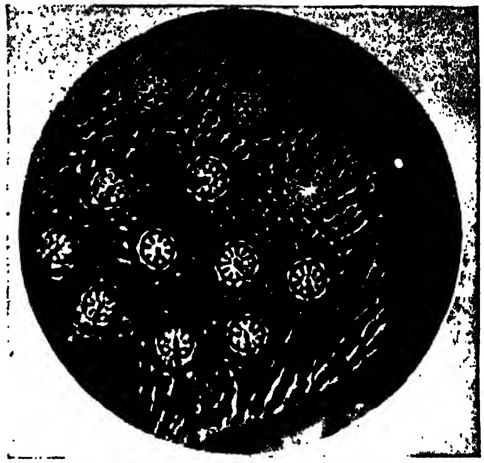
In all microscopes of this kind, only one eye can be used. This is very fatiguing. Microscopic study is indeed the most laborious of all scientific pursuits. The physical strain of long-continued investigation, carried on with the highest powers of the microscope, is very great, and there is combined with it an incessant mental effort which aggravates the bodily labour. Happily, Mr. F. H. Wenham discovered in 1860 a new way of using the microscope, which now often makes the use of the instrument a pleasure instead of a wearisome task. He designed a microscope with two tubes and two eyepieces. The right-hand tube was straight and fitted with an objective; the left-hand tube was fitted into the side of the main tube.

When the stream of light-rays passed through the lenses of the objective, and emerged into the main tube, they struck against a prism. This was a piece of glass so shaped that it divided the stream of light-rays into two portions. The left portion passed uninterruptedly through the

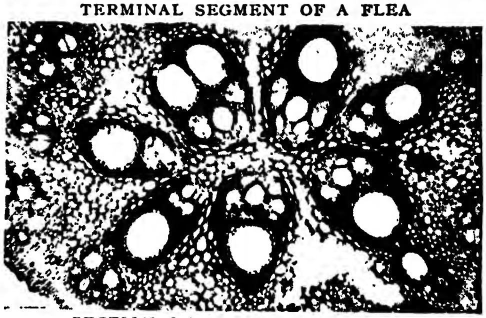
main right-hand tube, and so to the right eye of the observer. The right half of the divided stream of rays was reflected first to one side of the prism, and then to the opposite side; thence it was directed into the left tube of the instrument, along which it travelled to the corresponding eye of the observer. In this manner there were produced two images of the one object lying beneath the objective.

And now we come to a simple technical point which we hope will illuminate the explanation already given of the action of the compound microscope. There were two images in the binocular microscope of Mr. Wenham—one image in the right tube, and one in the left. Both these images, it must clearly be understood, were invisible images. They could only be seen by placing two pieces of paper at those spots in the two tubes where the two divided streams of light-rays separately came to a focus. Naturally, the two tubes differed in length, the eye-piece of the left-hand side tube being farther away from the object than was the eyepiece of the straight main tube. This produced a curious effect. The rays in the side tube had to travel farther, after they had formed an image at the focus and had there crossed and spread out again. In thus travelling, they spread out more, and the result was that they produced in the left eyepiece a more magnified second image than that which the shorter rays produced in the right eyepiece. This disagreement, however, was easily corrected by making the lenses in the left eyepiece lower in magnifying power than those in the right eyepiece.

It is worthy of remark that Mr. Wenham nobly presented to the public his important invention. Had he chosen to retain his exclusive right to it, he would have made a large fortune from his discovery. Microscopes in which both eyes can be used are not only more restful than monocular instruments, but they have some very valuable properties. They give what is called a stereoscopic vision. A simple experiment will explain what this is. Set upright on a table a thin book about an inch thick and five inches in width. The back of the book, where the title is usually printed, must face the observer, and be in an exact line with his nose, at a distance of about eighteen inches. Each eye will now be able to see a different side of the book; the right eye the right side, and the left eye the left side. When both eyes are simultaneously employed, the book appears

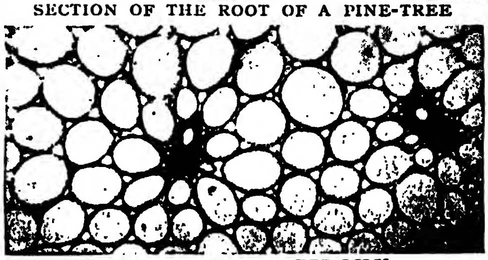


TERMINAL SEGMENT OF A FLEA



SECTION OF THE PEPPER PLANT

SECTION OF THE ROOT OF A PINE-TREE



SECTION OF A WATER-LILY

THE HEAD OF A GADFLY

ANTENNÆ OF A MOTH

THE TONGUE OF A MASON-BEE

to be very solid, and to have a decided depth. No confusion arises in the mind of the observer through the blending of two images of the same object, taken from two different standpoints. The same effect of depth is produced in the stereoscope, where two photographs, placed in different positions, are simultaneously viewed through the instrument. The depth dimensions are revealed in a wonderfully vivid and distinct manner. By means of the binocular microscope, in which this stereoscopic vision is obtained, we are able to examine the structure of minute living objects with remarkable ease.

Up to about 1884 England was supreme in the art of making microscopes, and a great deal of the theory had been worked out by the English men of science. Mr. J. J. Lister, the father of Lord Lister, did much to discover some of the principles of the scientific microscope. The older instruments, however, had two grave faults, which made them useless in the finest sort of work. One of these defects is called spherical aberration. As a lens has a curved surface, it is thicker in the middle and thinner at the edges if it is a convex lens, and thicker at the edges and thinner in the middle if it is a hollow concave glass. Let us take the case of a convex lens, with a stream of light-rays falling on its entire surface. The light-rays that pass through the thin edges will be bent in a different degree from those that pass through the thick bulging glass in the middle. Thus the rays will follow different paths, when they emerge from the glass, and they will not meet in a focus. That is to say, they will not produce an image, but only a wild and useless distortion of the object which it is vainly wished to magnify. So, before the compound microscope becomes of any practical use, this spherical aberration has to be corrected. Another lens of a different shape is fitted to the uncorrected lens, in such a way that all the rays are brought to the same focus. For example, a convex lens with two bulging curves has adjusted to it a glass one side of which is flat, and the other side of which is concave and hollow, so that it fits exactly on to one of the bulging surfaces of the uncorrected lens.

This, however, leads to another grave defect, which for many years was despairingly regarded as irremediable. Here we arrive at the fundamental realities of the science of the microscope. Hitherto, for the sake of simplicity, we have been talking about streams of light-rays. We have

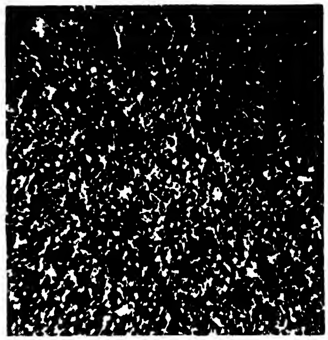
THE EGGS OF A MOTH

THE EYE OF A COCKCHAFER

THE TONGUE OF A FANTAIL FLY


CRYSTALS OF SALT


THE EDGE OF A KNIFE

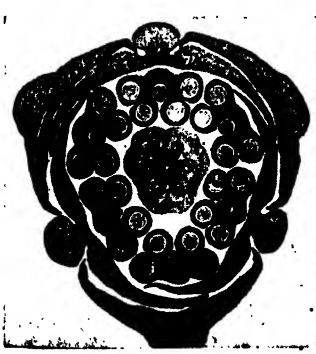

DUST ON A SHELF

pretended that a light-ray was a simple, definite thing. But, as a matter of fact, white light, as is now generally known, is formed of a series of waves in the ether, and these waves are of very different lengths. When a ray of light passes through a three-sided piece of glass, the different waves are separated; and when they emerge from the three-sided glass and fall against the screen, they form a band of rainbow colours. The same thing happens when they pass through any kind of lens, concave, convex, and so on. The white light is decomposed into a series of colours—violet, indigo, blue, green, yellow, orange, and red. Each of these colours is separated from the other, and each makes a faint image of the object which is being magnified by the lens. This is called chromatic aberration.

The problem was to bring all the coloured images together at one focus. Only by this means could the compound microscope be developed into a perfect instrument of scientific research. What was wanted was a variety of glasses of different densities, but, after about a hundred years of search, only two kinds of glasses could be discovered. These were crown and flint glasses. Flint glass is slightly denser than crown glass, and it has more dispersive power

When this fact was clearly known, it became possible to correct two colours, by making a lens partly of flint glass and partly of crown glass. A piece of flint glass was ground hollow on one side, and made flat and straight on the other side: a lens of this shape is called plano-concave. A piece of crown glass was then made into an ordinary convex lens, with two bulging surfaces. The lower surface fitted exactly into the hollow space in the flint lens, and by cementing it in this position there was formed a doublet lens. The flat flint surface was placed above the object required to be magnified.

The light-waves coming from the object passed through the flint glass, and were, of course, broken into waves of coloured light, each stream of coloured waves being bent differently. A wave of red light is much longer than a wave of violet light, so the much shorter violet wave was affected most The various streams of coloured light emerged, widely scattered, from the flint glass, and entered the crown glass, and here their paths again were altered. The result was that two streams of coloured waves were at last bent somewhat in the same direction, and when they came to a focus they formed a two-coloured image.


THE BUD OF A LILY


CRYSTALS OF NITRATE OF POTASH


SEWING-COTTON AND FINE SILK

The other streams of light-waves formed a series of fainter images, which were not only useless, but very confusing. Microscopes—called achromatic microscopes—were made that blocked out all the unfocussed images, and left only the double-coloured image to be transmitted to the eyepiece and studied by the observer. Unfortunately, even this image was not free from defects.

A Great German Student who Found what Must Be Before Inventing It

So the matter remained until Professor Abbe, a great mathematician of Jena, entered into an arrangement with Dr. Schott, who was interested in glass-making. These two Germans obtained from their Government a subsidy, and began a series of very important researches with a view to discovering new kinds of glass with just the density required to bring all the various coloured waves of light to the same focus. The work of research lasted several years, and in 1884 the new microscope was made, and in 1886 it was put on the market. Not only did it contain a new glass, fluor glass, but it embodied some new and absolutely vital principles of optical construction at which Professor Abbe had been working since 1873. Professor Abbe was, in fact, the father of the modern microscope of extremely high power.

He created a profound revolution in the mathematical theory of the instrument, and he worked out his theory on paper with such correctness that he was able to show exactly what the microscope could be made to do. He knew exactly what densities and curved surfaces were needed, long before the things he wanted were discovered. Thus he was able to give directions to the men who worked with him at the practical part of the business. They had only to follow the lines of research he had worked out by mathematics. Abbe never claimed the subsidy offered by the German Government, for his plan of research was so well laid that the discoveries were effected before the money was needed.

The Wonderful Adaptation of the Microscope to the Varying Length of Rays of Light

The firm of opticians with which Professor Abbe was connected has recently discovered a way to make use of the difficulty of the varying lengths of light-waves, instead of reducing them to a uniform focus. Red waves are about one-30,000th of an inch long, while violet waves are only one-60,000th of an inch in length. By means of the short violet waves objects can be distinguished which are twice as small as those which can be distinguished by the long red waves. The mean wave-length of light is one-47,000th of an inch, so that if the shorter violet wave could be used it would enable an observer clearly to distinguish minute things which, if viewed through the most powerful of microscopes in ordinary light, would only appear blurred together. Naturally, the shorter the light-wave which falls on anything and then bounds back from it, the more detail the wave will carry to the eye. This was clearly seen when a microscope was invented to be used only with violet light. Infinitesimal markings below the range of the wave-length of ordinary light were clearly perceived with lenses especially shaped and constructed to deal with light-waves only one-60,000th of an inch in length. Then came the ultimate advance of microscopic power in the ordinary way.

As is well known, there are much shorter waves of light than the shortest of the violet waves. The ultra-violet light, however, is not visible to human eyes. Its waves are too short to make any effect on the dark screen at the back of our eyeball. What added to the difficulty was the fact that no known kind of glass was capable of being used to bend ultra-violet light in the way that ordinary light is bent by lenses made from crown and flint glass.

The Latest Advance in the Construction of Microscopes

However, Professor Abbe's firm resumed its experiments, and succeeded at last in making lenses out of molten quartz. By means of these quartz lenses there was constructed a microscope which could be used with ultra-violet light. The image produced in the quartz eyepiece of the microscope was, of course, invisible to the human eye. Thus it was impossible for the observer to focus the lenses, so as to obtain an exact definition of the objects, which were sometimes one-240,000th of an inch in size. But by an ingenious arrangement this difficulty was overcome. The invisible image was projected from the eyepiece against a special screen, and on this it produced an image by the chemical action of the ultra-violet light. The microscope was then adjusted so as to give as much brilliancy as possible to the image, and a photographic camera was attached to the eyepiece, and a photograph was taken on a plate which had been made sensitive to ultra-violet light.

The microscope for ultra-violet light represents the ultimate advance practicable on Abbe's theory of the limits of the powers of the microscope. It is very important, however, to get a clear and definite idea

of what this limit is. There is no practical limit to the magnifying power of a modern microscope. If a single dot, of any size whatever, is placed beneath the objective of a first-rate instrument, that dot will be magnified so that the eye can perceive it. There is a very minute animal called a rotifer, which is found in great numbers in ponds. Some kinds of rotifers are invisible to the naked eye. If, however, a man cared to go to a great and useless expense, he could probably have made a microscope which would magnify one of these rotifers to the size of a windmill. It would, however, look like a windmill in a thick mist. Little or none of the exquisite detail of the rotifer would be perceived—one would, indeed, scarcely be able to make out whether it was a windmill with whirling sails, or an animal surrounded with revolving organs.

The Power that is Much More Important than Magnification

There is something more important than magnification. This important thing is called resolution. Supposing two lines are drawn so close together that one hundred thousand of them would only occupy one inch. A microscope that would "resolve" those two lines in ordinary light, that would make them stand away from each other so that they could be clearly seen, would be a microscope of very remarkable power. In fact, the resolution of lines ruled a hundred thousand to the inch is a power possessed only by the very best of modern microscopes. In this respect a microscope can be compared with a telescope. If a very good telescope is pointed at a distant star, it makes the star seem smaller; if the finest telescope in the world is pointed at the same star it makes it appear still smaller; and sometimes it makes it appear so small that the star is resolved into two minute points of light. The two minute points of light are the reality. It is a double star, and the stars are so close together, and at such a vast distance from our earth, that only an instrument of tremendous power can disentangle them from each other, and get a separate image of them.

New Wonders of Microscopy that are on the Eve of Discovery

And now we come to the achievement of the impossible—the ultra-microscope. One of the smallest known pieces of matter existing as a distinct thing is a molecule of hydrogen. For a long time chemists have vainly been endeavouring to study matter in its molecular state, but it now seems likely that a new kind of microscope will enable them to do this. It is a good many years ago since Tyndall, following out an idea of Faraday, came near to accomplishing an apparent miracle. He used an ordinary kind of microscope, inferior to the best now obtainable, but he employed a new and curious kind of light. Tyndall was, we believe, the first man to discover why the sky is blue. He found that its blueness was due to the fact that the waves of light from the sun struck against very minute particles in the air, and became what is called polarised light.

This gave him the idea of using light in such a way as to reveal invisible particles of matter. By the use of Tyndall's method, Richard Zsigmondy, of Göttingen, has evolved, with the help of Dr. H. Siedentopf, the ultra-microscope. A small and extraordinarily intense beam of electric light is directed against the objects which it is wished to see. The waves of light strike against the objects and rebound, and are bent out of their path. They fly away in all directions, and some of them enter the lens of the microscope placed close above, and from the lens they are sent to the eyepiece. All that is really required of the particles against which the light-waves strike is that they should be capable of reflecting light.

How the Cinematograph May Help the Future Disclosures of Science

Particles of gold one-sixth of a millionth of an inch in size can be examined in this manner. Only a slight improvement is needed to make visible fragments of matter no larger than a hydrogen molecule.

Perhaps the cinematograph may become the ultimate instrument in ultra-microscopy. In this case, a narrow and very intense beam of ultra-violet light would have to be used; and the cinematograph, with specially prepared plates, would be attached to the eyepiece. When the plates were developed and printed and sent through the machine, they would throw on the screen images of the molecules, though the images would not show the actual size and details of the particles. This Dr. Zsigmondy does not aim at obtaining. He will be content if he can discern the number and the motions of the molecules, and see, if possible, how they unite in chemical combinations. He has already obtained some successes of this sort; and he now prophesies that the "ultra-microscope will prove a powerful weapon with which to attack the many problems confronting the chemist, the physicist, and the biologist."

QUARRIES FOR THE CROCKERY CUPBOARD

CHINA CLAY PIT AND WORKS, AT CAUDLEDOWN, NEAR ST. AUSTELL, IN CORNWALL

LOWER PART OF THE LANTERN CHINA CLAY PIT AND WORKS NEAR RESCORLA, CORNWALL

The discovery of china clay in this country not only enabled our potters to compete with the Chinese as porcelain-makers, but also led to the export of clay to China.

ART OUT OF CHAOS

How the Dust of Mountains is Softened and Kneaded and Moulded and Hardened Into Things of Use and Beauty

POTTERY—THE WORLD'S OLDEST INDUSTRY

THE manufacture of pottery is the oldest and most universal of the creative industries of the world. Just as to-day rude forms of pottery are made by the tribes that remain in a state of savagery, so, among the buried records of the first men whom we can trace, pottery vies with primitive weapons for the most distinctive place.

When Canon Greenwell opened the sepulchral mounds—chiefly in Eastern Yorkshire —on which he based his book about "British Barrows," he found 108 examples of ancient pottery, dating back beyond all written history. Beside the bodies of those men of vanished races, in company with their rudely chipped weapons, were vases, food-vessels, drinking-cups, and small bowls, apparently for holding spices or libations; and in many cases the larger vases or urns contained the bones of the dead, partly consumed, or calcined, by fire. And these abundant remains of the earliest work of men's hands show that an artistic impulse was already felt. A large part of the pottery associated with the most distant dead had been decorated, so as to make it an object of admiration in the eyes of its designers, as well as an adjunct to ceremonial observances.

In every part of the old-time world pottery had a place. Among the ancient cave-dwellers of Central France, as among the lake-dwellers of Switzerland, earthenware was clearly in common use. Wherever excavations have uncovered the domestic haunts of these dispossessed races, as well as their burial mounds or stone-sheltered graves, it has been seen that pottery of two kinds was produced; and that while the plainest and roughest vessels would serve for daily needs, far greater care was bestowed on the hardened wares designed for ceremonial purposes. Art was introduced, perhaps to honour the dead, perhaps to propitiate whatsoever spirits were supposed to have the dead in their company. The sides, and often the bottom, of the sacred urns were ringed round with ornamental bands marked in the clay; and between the bands designs were drawn in short, straight lines, inclining towards each other at varying angles. The strength of the artistic instinct of man in his most primitive state is remarkable. Whether ruling lines in wet clay by the use of an indenting string or fibre, or drawing the outlines of the animal he was hunting, on the handles or blades of the weapons with which he was hunting, the primeval man seems to have felt the need for ornament. Artistry was a twin birth with utility; and to-day the use of clay in manufactures is divided between the convenient and the beautiful.

That the making of pottery should be the oldest of all domestic manufactures, and indeed coincide with the making of weapons, is so natural as to be inevitable, everywhere. In its simplest form earthenware needs no tools. The human hand suffices. The wildest man who runs the woods must feel the need of some contrivance in which he can store his beverage. He sees that the clayey soil holds the water where he stickily paddles, and that the clay is moulded by his feet. He sees that when the sun has dried up the water it hardens the clay, which again is softened by the wet. What, then, can be simpler than to scoop up the soft clay, knead it and mould it, and set it to dry and harden in the sun, into a reservoir for slaking thirst, or a jar-shaped storage place for food that the animal thief cannot readily rob? The smallest child can mould clay, and likes to do it.

When the use of fire became common, the quickening of the sun's burning and the greater hardness of fire-baked pottery would be suggested immediately, and the hand-

shaped clay vessel, carefully baked, would soon become an object of pride. So simple is the process that among the least-inventive races it has been independently evolved everywhere, and the rapid improvement of pottery has proceeded spontaneously in all parts of the world where the people have reached a fair average of intelligence. Indeed, the great difficulty in tracing the rise of the pottery manufacture on a world-wide scale arises from the fact that in every direction there have been spontaneous and independent invention and improvement. It is the one example of a universal manufacture without great need for borrowed ideas.

The Wonderful Wheel that Was Invented Again and Again

Pottery of some kind may be made everywhere What kind it shall be will depend upon the ingenuity of the people of each locality, and the quality of the clay that is available. Before there was much interchange of commodities between distant nations, especially of such perishable goods as earthenware, every considerable community that had in it sufficient intellectual vitality to build up a distinctive state had evolved its special style of pottery, and in many instances had advanced it to a high state of perfection. Not only use but beauty had been attained. Under such circumstances it is absurd to talk of priority in manufacture. That simple mechanism the potter's wheel, which came early to the assistance of human hands, arrived as a matter of course in many places. It was independently invented, no doubt, again and again. The Greeks claimed it as their discovery. But it was known to the Egyptians and the Chinese long before the Greeks had emerged as a conspicuous or individualised people. Various mythologies tell of its bestowal as a gift from the gods. The gods that gave it birth were Necessity and Invention; and it came as soon as it was wanted, alike in Egypt, in Chaldea, in China, and in Peru, a simple instance of that wonderful reaching forward inherent in mankind, that has never ceased and never will, and that, judged broadly by its results, is named Progress, and is the sign-manual of the Divine.

Kinds of Pottery that Merge Into Each Other Where They Meet

All kinds of pottery may be divided into three groupings—earthenware, stoneware, and porcelain. Earthenware covers an enormous variety of qualities and styles, from the plainest household utensils, costing a few pence, to the most elaborate pieces of artistry, in which the charms of form, texture, design, and colour are combined. The distinctiveness of its manufacture is found in the low heat at which it is baked.

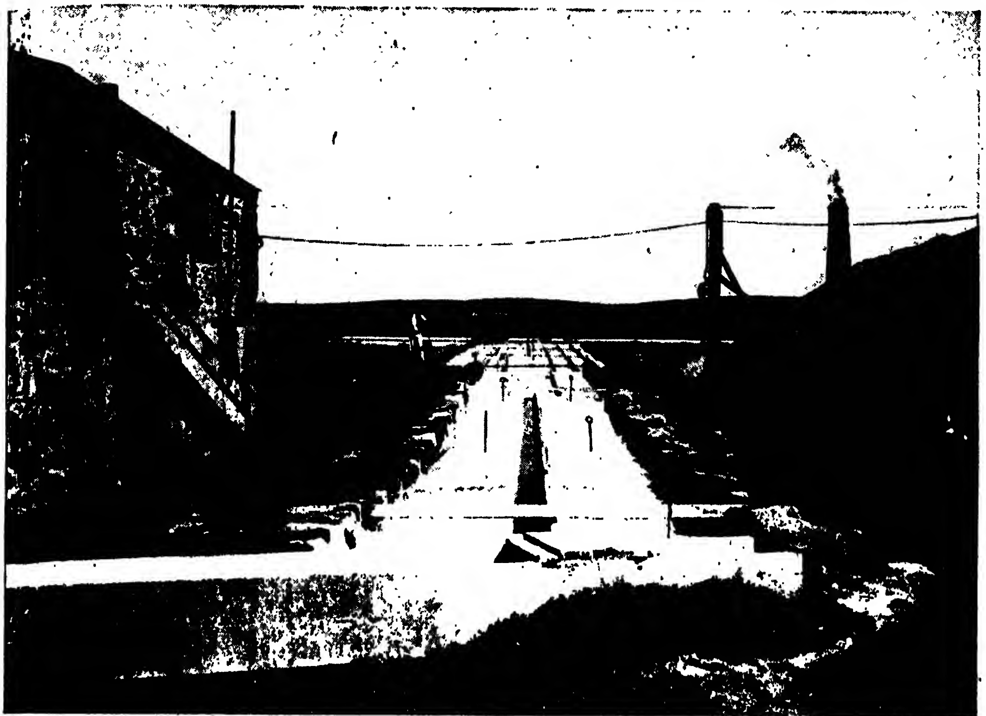
Stoneware, on the other hand, is baked at a great heat, is much harder, and as a rule is used for commoner purposes. Porcelain, which sometimes is soft paste and sometimes and more truly hard paste, is baked at the highest temperature, and when sufficiently thin is shell-like and transparent. Each of these three kinds of pottery is made with a wide variety of material; and earthenware in its finer forms approaches porcelain so nearly that only an expert can discover the distinction.

Glancing broadly over the various forms of earthenware and porcelain of the past and present, one must see that by whatever name each may be called, or whatever its place of origin, six considerations have determined its quality. First, there is the choice of the clay, or of the materials that are mixed with the clay to give it the characteristics that are needed. Primitive pottery depends for its colour and consistency almost entirely on the nature of the clay of its particular locality.

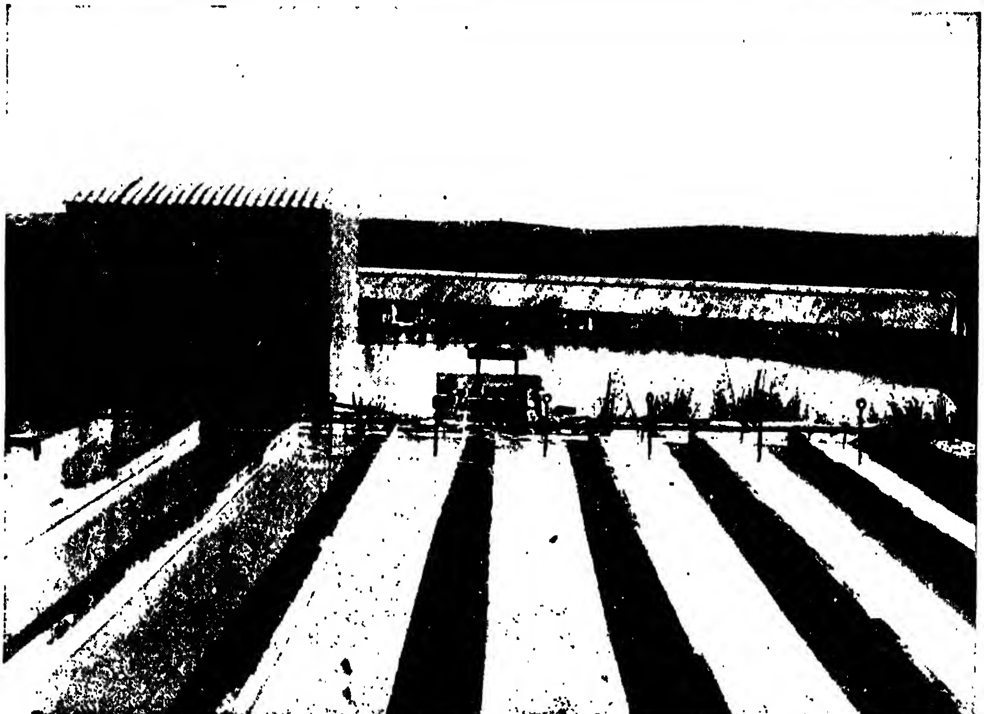
The Missionary who Told Europe About the Wonders of Chinese Pottery

The supremacy of China for porcelain was established originally by the possession of clays of extraordinary purity, and their manipulation with great skill by a minute sub-division of labour. The letters from China of the Jesuit missionary Père d'Entrecolles, which first described in detail for Europeans the methods of Chinese manufacturers, at the beginning of the eighteenth century, point out that the best chinaware can only be made in certain places, and that attempts to attract the workmen elsewhere have led to non-success in their work. In short, the workman must go to the clay. This is generally true, though it is modified by the fact that to-day Cornish white-burning clay is exported to all the countries where superior pottery is made. Next comes the working of the clay, so as to give it, in composition and consistency, the right qualities. This is still done, in principle, by the same methods as were in force two thousand years ago. Père d'Entrecolles tells how in the case of the finer grades of Chinese porcelain a hair or a grain of sand left in the paste may ruin the whole work. In all countries in the past the most rigid secrecy has been maintained respecting the composition of the various additions made to the crude clay.

THE PURIFYING OF THE CHINA CLAY



"DRAGS AND MICAS" AT THE LANTERN CHINA CLAY WORKS NEAR RESCORLA, ST. AUSTELL



CLAY AND WATER RUNNING FROM THE "MICAS" INTO THE SETTLING-PIT BELOW

The china clay, which gives plasticity to the paste for porcelain, is broken up and mixed with water, the liquid being run into channels called drags, where the heavier materials settle, and then into micas, where the finer materials settle. From the micas the liquid flows into settling-pits.

Then follow the designing and shaping of the article concerned. Vessels graceful in outline were built up by primitive man before the invention of the potter's wheel. In some of the specimens found in the barrows on our downs and moorlands, matting or wickerwork has been used as a shaping groundwork or body, on which the pliable clay has been moulded, inside and outside. In all lands and times there has been, of course, a disposition to repeat conventional designs, with the result that any single work of art has been produced by many minds and hands.

D'Entrecolles mentions that in the best centre for manufacture of Chinese porcelain, during the palmiest days of that world-wide trade, as many as seventy workmen were employed successively on one piece, and often it was built up in parts. One result was a failure in new designs. No one could model and carry through new work as a whole; and when porcelain became a present for kings, and the Emperor of China sent an order for wares that would express ideas of his own, the carrying out of these ideas was found impossible, and the native Christian pottery-workers asked the Jesuit Father to use his growing influence in petitioning that the order should be withdrawn, and no more workers be bastinadoed for failing to accomplish the impossible.

Work so Delicate that a Touch by a Rough or Greasy Hand Will Spoil It

In various countries—though there is always a tendency towards stereotyped reproductions—almost every device of art has been used in the designing, moulding, and decoration of innumerable forms of pottery.

The next feature common to all ceramic art is the baking, or firing, of the wares. This is often done three or four times over, as will be explained later; and the danger of it in the case of delicate fabrications, like the choicest examples of porcelain, accounts to some extent for the expensiveness of the articles finally produced. The touch of a greasy hand in the oven will spoil a piece of porcelain, or one piece touching another, as D'Entrecolles pointed out two centuries ago: "The furnace is sometimes opened, to find the pieces and cases in which they have stood reduced to a mass as hard as rock, for it is not easy to regulate the fire, as the state of the weather instantly changes its action, with the quality of the material it acts upon and the wood which keeps it going."

Between the firings comes the process of glazing or enamelling, rendering the surface smooth and non-porous. The use of glazes has been known from early days, as is seen in Egyptian pottery, their alkaline glazes however, proving very uncertain. Lead glazes are most general for ordinary earthenware, felspathic glazes for hard-fired porcelain, and salt glaze for stoneware. Glazes are put on sometimes over, and sometimes under, colouring and patterns. Pottery that stops as it was before the glazing stage is called "biscuit." After the glaze is put on another burning takes place.

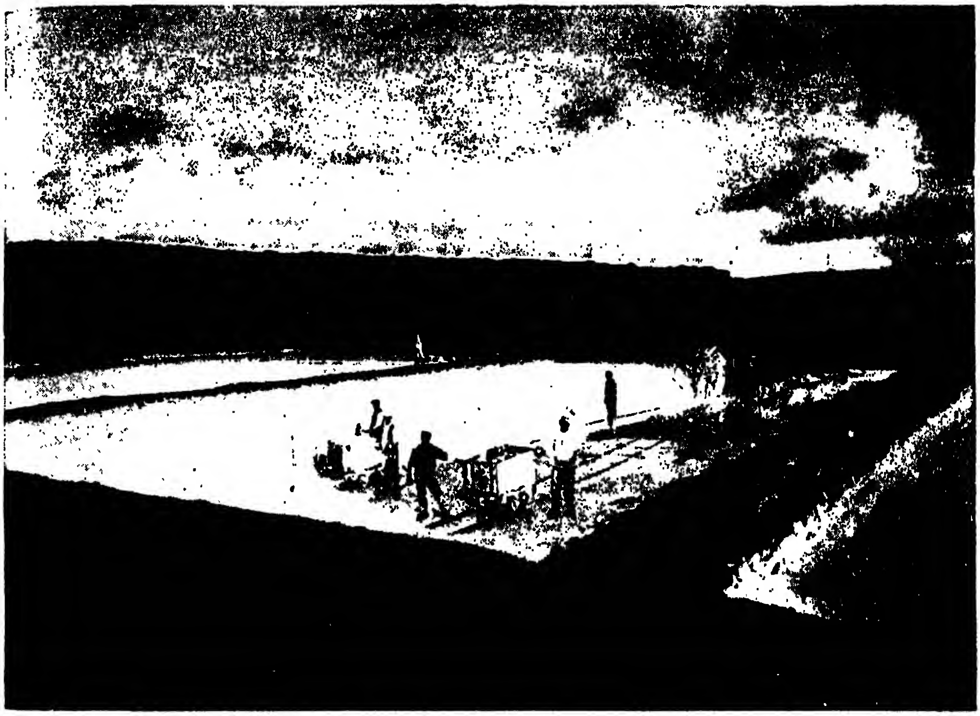
Where the Oriental Sense of Colour Outmatches All Our Western Mechanical Art

The colouring and painting of pottery is the last stage through which it passes; and colour as much as texture has given certain types of work an artistic value that has been recognised in all parts of the world. Pottery was originally coloured by the colouring matter of the clays used. It is now painted or subjected to transfer printing in the most elaborate manner, though no mechanical processes can produce the wonderful effects of the Eastern colourists.

From the sun-baked pottery of primeval man to the gorgeous art treasures of the most delicate porcelain is a long story, and telling of it at large would introduce almost every nation, ancient and modern. The earliest pottery of which we have specimens is undoubtedly Egyptian, for though China claims extreme antiquity for her industry, her proofs are unsatisfactory, and her samples non-existent. She came to the front as the producer of the world's most delicate earthenware rather more than seven centuries ago, when a present of Chinese wares from the Emperor Saladin to the Emperor of Damascus made a noise throughout the world by its astonishing beauty. Nearly 3000 years before that, Egypt was producing pottery of a type that has been claimed as porcelain.

World-Wide Exchanges in the Ancient Days of Delicate and Precious Products of Taste

At the same period, and later, the Mesopatamian empires were using baked earthenware in many ways; and to-day the mouldered remains of their clay-built cities cover their clay-written libraries. The Phœnicians had a certain rude expertness in earthenware, and undoubtedly used it freely for domestic purposes. Greek pottery had all the Greek taste in beauty of form and refinement in ornamentation. When the Chinese sold their wares by sea to the Saracens they were trading with the men best able to appreciate their skill, for, probably by transmission from the Persians—adepts in the art—the Mohammedan



DEPOSITING-TANKS, LOWER ALVIGGAN CHINA CLAY WORKS, ST. MEWAN, CORNWALL

INTERIOR OF THE DRYING-FLOOR AT THE WHEAL ROSE WORKS, BUGLE, NEAR ROCHE

From the settling-pits the china clay is passed on to the settling-tanks, where it is deposited, and attains a consistency that allows of its removal to the drying-house, where the moisture is evaporated by heat.

power itself was coming to be regarded in the West as pioneering Eastern architecture and the gorgeousness of Eastern ceramics.

When they had established themselves in Spain the Moors were accepted as the teachers of Europe through the brilliant lustre of their earthenware. But the real revival of the potter's art in Europe, like all other resurrections of art, came about through Italy, and more particularly through Florence, though in all probability the necessary inspiration and technical skill were originally sought by the Italians in Spain; and for generations Italy joined hands in manufacture with Spain through the Balearic Isles, whose majolica ware was a direct link with Moorish influence.

Progress of the Art of Pottery Throughout Europe After Its Reception from the Moslems

Afterwards Italy developed her manufacture of majolica ware, with its tin glaze or enamel, and the art passed with Catharine de Medici into France, where Palissy was conducting his heroic experiments, and eventually the making of soft-paste porcelain became identified with Rouen, St. Cloud, and Sèvres. Hard-paste porcelain was first established in Europe at Meissen, near Dresden, by the unfortunate Johann Friedrich Böttger, who probably was put on the track of the right materials by the agents of the Elector of Saxony, engaged in bringing together his rare collection of Oriental porcelain. Within a dozen years of Böttger's early death, Meissen porcelain was supplanting that of China in the Near East.

By the middle of the eighteenth century all the chief European nations were busy making pottery of fine as well as useful kinds; and British works of a distinctive character were established at Chelsea, Bow, Derby, Worcester, and in Staffordshire—to mention only the most noteworthy localities and varieties—and British pottery attained an influence felt throughout the world, owing largely to the persistent experiments and the forceful character of Josiah Wedgwood.

The Great Potter Pioneers Whose Success Gave Europe Porcelain

On the human side there emerge, from this growth of the ceramic art, here but scantily outlined, three personalities that will ever be remembered—Bernard Palissy, Johann Friedrich Böttger, and Josiah Wedgwood. Palissy, the son of a poor worker in glass, was born about 1509, to the south-east of Bordeaux. Having learned the trade of glass-painting as a youth, he wandered in the practice of his business, which he varied with portrait-painting and land-surveying, over France, the Low Countries, and part of Germany, till, when nearing thirty years of age, he married and settled at Saintes, to the north of Bordeaux. At that time the manufacture of earthenware in France remained in quite a rude stage; and when an enamelled cup of Italian make came into Palissy's hands it was a revelation, and he determined to devote himself to the discovery of a glaze that would enable him to pursue the career of an art potter, though he knew nothing of the ingredients of such wares, nor of the process of baking them.

Fired by an ambition which became a passion, he began experiments that were continued for sixteen years through almost incredible difficulties. He pounded all kinds of substances in the hope of finding the constituents of an enamel, broke up earthen pots by the hundred, and baked them afresh in a furnace of his own making with his pounded substances and chemicals till he had spent all his money in earthenware and fuel. Yet his experiments yielded no satisfactory result.

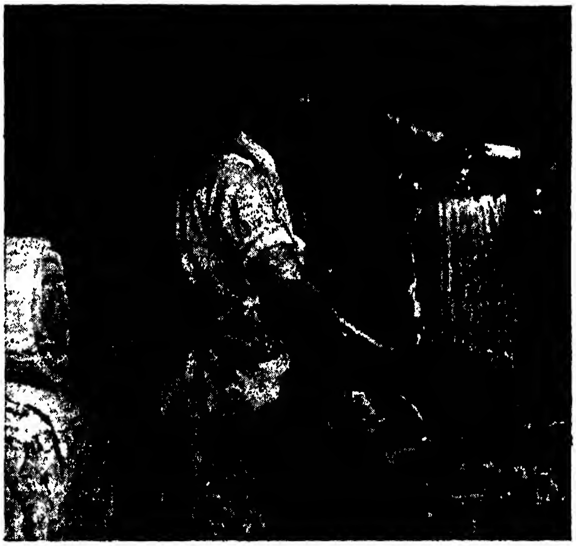
A Man of Heroic Heart Whose Faith in His Invention Never Gave Way

In tile furnaces and glass furnaces he secured a place for a retrial with his broken pots and compounds whenever he had earned a little money by land-surveying; and after years of such effort and failure he secured at last a single specimen of white enamel. Then he built himself a furnace, baked some vessels of his own making, and covered them with his enamel compound for a second baking. But the enamel would not melt. For six days and nights he fed the fire, and the enamel did not melt, and his pots were now so over-baked as to be spoilt. With borrowed money he bought more fuel and more pots, covered them with his obstinate compound, and re-lit the furnace, but all his fuel disappeared, and the enamel had not melted. The garden palings, the household furniture, the shelving from the walls were thrust into the furnace to raise the heat; and then, while his wife was rushing through the town exclaiming that her husband had gone mad, the enamel melted and coated the rough pots with a white glaze that realised Palissy's impassioned hopes.

What Palissy suffered during these years from his intractible materials was, he admitted, scarcely less disheartening than

the reproaches of his wife. And, indeed, after the discovery of the enamel, some eight more years were spent in experiments before the potter's perfected discoveries could take the form of saleable wares. Then the ornamental crockery for which he was both artist and craftsman began to be popular, and Palissy became "inventor of rustic figulines" to the king.

Palissy was a Protestant; and five years after his success began he was seized and imprisoned at Bordeaux, and would probably have gone to the scaffold had not the Constable of France needed him to produce an enamelled pavement for his new country seat near Paris. He was accordingly taken to Paris, to work under the patronage of the Constable and Catharine de Medici. Here he lived twenty-one years—surviving the Massacre of St. Bartholomew owing to the special interposition of Catharine—and became a philosopher, a writer, and in some degree a scientific reformer. But neither age, renown, nor usefulness proved a lasting protection. At the age of seventy-six he was thrown into the Bastille because of his Protestantism, where he died in his eightieth year, true to the faith that was in him, and proving his own words that constraint has no effect on him who knows how to die. Palissy's whole career showed him to be a man of heroic soul.



PASTE FOR POTTERY, AFTER FINAL MIXING, READY FOR USE

Böttger was cast in a ruder mould, and had a strain of the charlatan in him, but his story is as romantic as Palissy's, notwithstanding its discordant tone. He was born at Schleiz, in Thuringia, in 1685, and apprenticed to a Berlin apothecary, in whose laboratory he claimed to have made gold. When King Frederick I., however, wished to replenish his purse from the young alchemist's skill, the sixteen-year-old lad fled, with a regiment of pursuers at his heels, and took refuge in Saxony, where the Elector protected him. Again he was in some danger because he failed to make gold for the Elector, but eventually he was put to work in the laboratory of Pschirnhaus, the chief chemist at the Dresden Court. Here he succeeded in making a kind of red stoneware, capable of a high polish, and resembling porcelain in texture, though not in transparency. At last he discovered the secret of a white porcelain, it is said by using the powder on his wig as an ingredient in his experiments. Böttger's success was his undoing. He was guarded day and night to prevent his escape with the secrets of his search, and the Elector established a Royal manufactory for the exploiting of his skill. Here Böttger was kept a prisoner and treated as a slave, notwithstanding urgent appeals for liberty; and under the stress of this inhumanity he lost his sense of dignity, became a drunkard, and died, a physical wreck, in his thirty-fifth year. The distrust and brutality of the Elector of Saxony defeated his own ends, for the workmen in the factory, absconding to avoid Böttger's fate, carried the secrets of the business with them, and so the making of porcelain spread through the Royal factories of Europe.

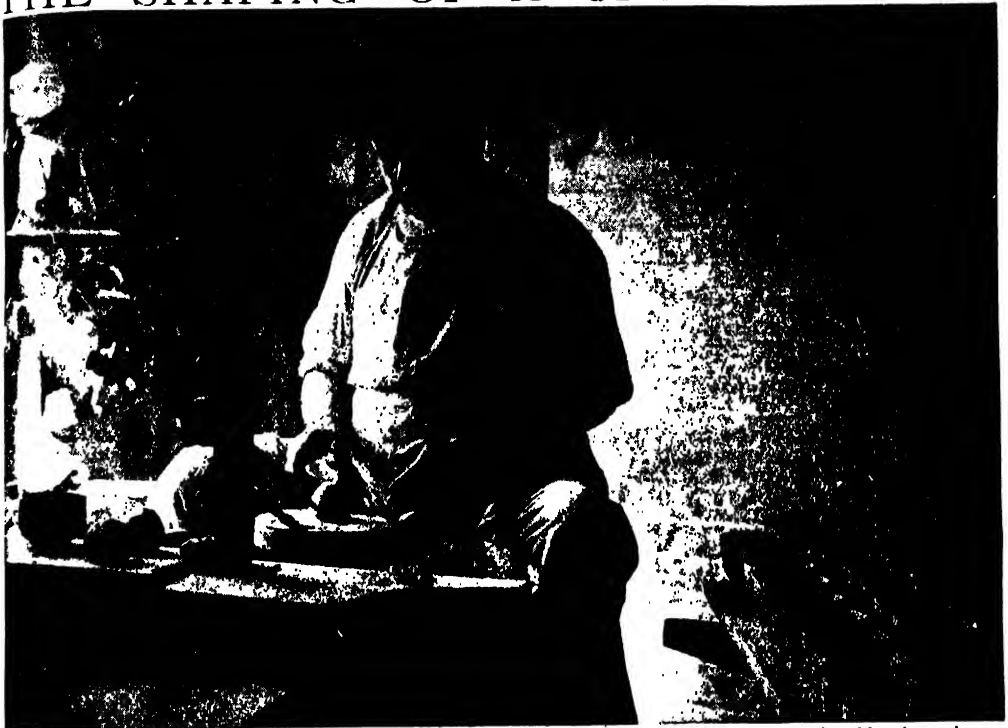
Josiah Wedgwood went to work as a potter at the age of ten. He was born at Burslem, in 1730, the son and grandson of a potter. Lamed by disease following smallpox, he only secured health later in life by having his right leg amputated. Perhaps, as was once suggested by Mr. Gladstone, this physical imperfection "sent his mind inwards to meditate upon the laws and secrets of his art." Beginning with a study of chemistry, he observed closely the properties of different kinds of clays and earths, and made experiments with fluxes and glazes, till after many failures and heavy losses he produced earthernware

THE POTTER MAKING DINNER-PLATES

Sometimes the potter shapes the article he is making entirely with his hands on the revolving potter's wheel, but often it is shaped by a mould, especially when many articles, like plates, have to be made of exactly the same size. In the picture we see the potter shaping a plate mechanically.

In this picture the potter is trimming the plate to exactly the right size. It is now in quite a damp state, and has to be carried away by the boy behind the potter to the drying-stove, where it loses its moisture and sets more firmly before being baked.

THE SHAPING OF A CHINA TEA-CUP



The potter is here shaping a tea-cup in soft clay paste on his revolving wheel. He first shapes the outside with his hands judging exactly the size and form.

Then the potter shapes the inside of the cup, every little touch of his skilful fingers being followed by a change in the form of the soft clay as it spins swiftly, like a top.

and porcelain that spread the fame of English pottery throughout the world.

Wedgwood was not only an experimenter, an inventor, and a rare man of business, but he had high ideals and fine taste. He knew the charm of classical art, valued form as well as texture and ornament, and called to his assistance the best designers. The work done by this broad-minded and capable man is perhaps best summarised in his epitaph. He "converted a rude and inconsiderable manufacture into an elegant art and an important branch of national commerce." In the criticisms that have been somewhat jealously passed upon him, it has been said that he converted what was perhaps a rude and inconsiderable art into a manufacture; but though undoubtedly Wedgwood was a great business organiser, the time had come for business organisation; and instead of criticising him because he was more than a potter—a captain of industry and far-sighted commercial campaigner—it is more just to own that he was all that, and at the same time "welded into one harmonious whole the prose and poetry of ceramic art."

How the Potter Moulds the Carefully Prepared Clay Into Graceful Shapes

The methods of making pottery are in essence the same all the world over, and apply largely to all kinds of ware. First the raw materials have to be ground in mills in water till they come out as a thick liquid. What materials are put into the mills, or are admitted into the mixing-tank where various liquid paps are blended, depends on the ware to be made and the formula used by the particular firm. In every type of pottery the proportions of the different ingredients vary. Thus, of kaolin, or china clay, Sèvres porcelain has 48 parts, while Dresden has 62 parts and Berlin 76 parts.

When the liquid ingredients have been completely mixed, they are in the "slip" state and capable of pouring. They are next dried till they become a tough dough ready to be shaped by the potter. Formerly "slip" liquid was used for the ornamentation of all kinds of articles, being poured, or dropped or dabbed on in a pattern, after a vessel had been shaped and burnt.

The clay that has been so carefully prepared and mixed, according to the chemical and experimental research of generations, is now passed on to the "throwing machine," or the potter's wheel, a revolving horizontal disc, on which it is moulded into the required shape, either by hand or by tools, as it is whirled round. There is no more striking process in all the operations of manufacture than this ancient one of raising graceful shapes by the action of the hand, the eye, and the flying wheel. The shaped vessel is then put aside to dry, till it is tough enough to be handled, after which it is placed on a turning-wheel, and more exactly shaped, trimmed, and smoothed. Many articles, particularly of the finer and more ornamental kind, are shaped in plaster of Paris moulds, into which the liquid clay is poured; or parts, such as handles and feet, are shaped in separate moulds.

The Baking that Transforms Soft Clay Into Hard Eartheaware

Other articles are formed partly by moulds and partly on the wheel, or moulds are used for the outside, while the inside is shaped by the hand or by tools. Up to this stage the working of pottery has had the dramatic quality of swift and visible formation.

The next stage is slow, delicate, and momentous. After undergoing a drying process, the article is baked in the biscuit-oven, biscuit-ware being the name given to it after this first firing. Each article is placed apart, so as not to touch any other article, in a fireclay receptacle called a "seggar," the number in each seggar varying, according to size, shape, and importance, from one upwards. The seggars are piled on each other high in a kiln, spaces being left between each pile or "bung" of seggars, with a hollow space in the middle of the kiln. There are usually eight furnaces to a kiln, and the flues pass between each sixth and seventh pile of seggars, so that forty-eight bungs of seggars make a full kiln, with a regular heat circulating all round each fireclay seggar. The whole is sealed up, and the baking goes on for forty hours or more. The contents of the kiln are then allowed to cool gradually.

The Glazing and Decoration of All Kinds of Pottery

A quick oven will take three days to fire and three to cool. In special cases of important and valuable work, as long as a month has been taken to fire, and half that time to cool. In some cases the "biscuit" stage completes the article, as with jasper and basalt ware, or a glaze is introduced at the first baking by throwing common salt into the oven at its hottest, the seggars being opened for the purpose. The volatilised salt, mixing with the silica in the surface paste, will then form an even glaze over the whole article. Sanitary tilings, stoneware jars, and bottles are thus made with a single baking, but more elaborate or ornamental vessels need repeated treatments.

We here see the potter contemplating a shapeless lump of clay on his wheel. He can mould it at will into innumerable forms.

By the use of his hands alone, and the swiftly turning wheel, he is shaping the lower part of a vase, using at once inside and outside pressure.

The vase grows under his clever hands until it takes an ewer-like form, but this is only a passing stage.

Here by the delicate measurement of eye and hand the clay has been transformed into a graceful vase.

SKILLED CRAFTSMANSHIP—THE MAKING OF AN ARTISTIC ORNAMENT

Under the potter's hand, or by the use of his shaping mechanism, the clay changes its contours constantly till the onlooker cannot guess at its final form. We see here the three processes by which an artistic ornament can be shaped. First the damp clay is solidly raised, then hollowed, and then, partly by hand, partly by tool, takes an artistic outline.

Pottery that takes a printed pattern receives it often at the biscuit stage from transfer-paper, the porous biscuit-ware absorbing the ink. It is put back in the seggar to fasten the colours, and then is dipped into a glaze composition, after which it is placed in the "glost" oven and baked a second time to harden the glazed surface. Great care has to be taken that the article is evenly dipped, and that it does not touch anything in the "glost" oven. If the glazing is successful, the pattern underneath the glaze comes out clearly. Ordinary ware, with or without a pattern, is completed at this stage, after being fired to a less heat than in the baking process, more gradually, and for a shorter time.

The further stage is where the article is decorated over the glaze. The colours and decorations are painted on the glazed surface with a hair-pencil, like painting on glass, and then a third firing is given, this time in the enamel kiln with a lower heat still, and, if possible, greater care, as the article is increasing rapidly in value through the work done upon it, and the growing delicacy of its character.

The marvellous range of the potter's craft is one of its most striking characteristics. It begins with a stone ginger-beer bottle, and ends with works of art that are priced in thousands of pounds. As to the value of many existing examples over this vast range there is considerable doubt, since antiquity is always being copied and counterfeited, and the expert in pottery is one of the most contradictory of his kind. Père d'Entrecolles sent word from China two hundred years ago that the Chinese were busy manufacturing the most valuable antique pottery with a skill that defied detection after the piece had been buried for a month or more in the foulest sewer. He pointed out that genuinely ancient pottery was usually found buried, because it was beautiful, and therefore valuable, and therefore needed at times to be hidden. And, being long buried, it showed signs that

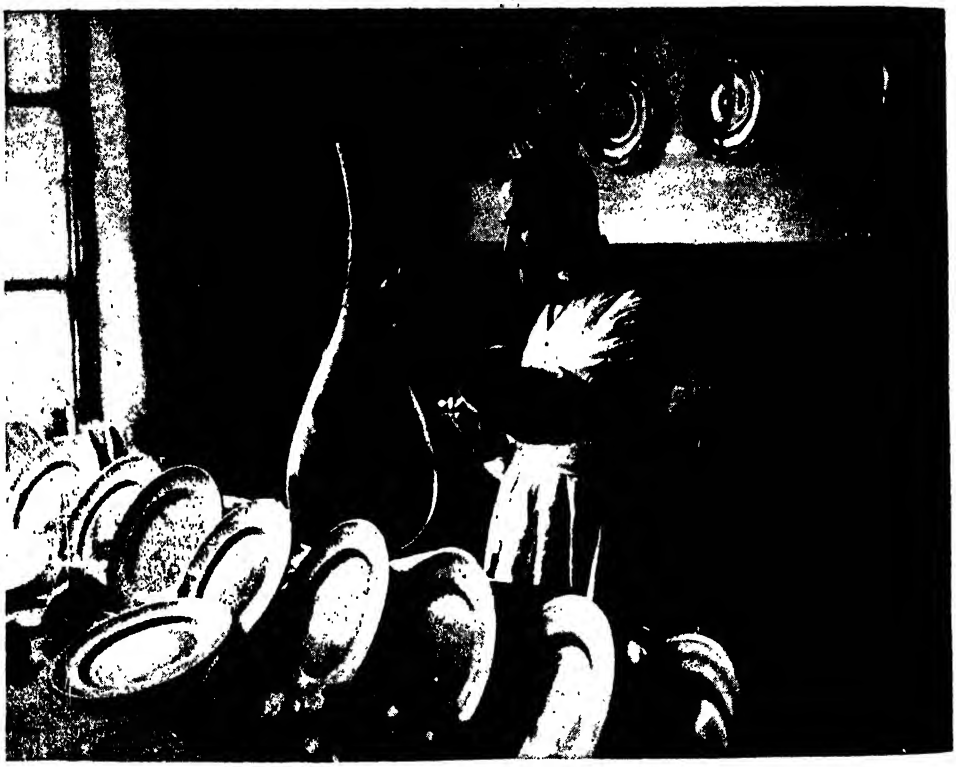
THE KILN WHERE CROCKERY IS BAKED AFTER DRYING

Pottery is packed into fireclay "seggars," which are piled on each other in a closed kiln, and baked for a length of time varying between forty hours and almost as many days.

could be easily imitated by shorter burial of imitations in a more drastic way.

An atmosphere of doubt hangs over the manufacture, and it is not created by the strife of trade-marks and their counterfeiting. Keen competition has marked the progress of the business from the first, with secrecy as a safeguard, and spying as a not uncommon resource. The most confident claims to originality are all contested. Who was it invented the salt glaze for stoneware? The answer often given has been Elers, the Dutchman, who entered the Staffordshire business late in the seventeenth century. It is quite clear that though the Elers brothers gave a useful impetus to Staffordshire industry, and made such changes for the better that one of the Astburys—a notable potter family—thought it worth his while to pretend to be an imbecile while working in their factory and picking up points, they did not invent the salt glaze, for it had been used on the Continent long before they came to England, and was adopted by Dwight, of Fulham, in his stoneware bust of Prince Rupert.

The art of pottery lends itself in a remarkable degree to imitations; and in that respect English potters have been particularly successful. Wedgwood in particular had the power to copy anything. In his day, the excavations of Pompeii were calling attention to the beauty of classical forms; and the great potter not only produced vases in the classical spirit, but copied with exactness the works of antiquity. The celebrated Barberini Vase, found near Rome and bought by Sir William Hamilton for £1000, was lent to Wedgwood by the Duke of Portland, who had bought it from Hamilton, and fifty copies of it were made with a wonderful fidelity. This reproduction of what is now termed the Portland Vase was regarded by Wedgwood himself as his masterpiece.



THE DECORATION OF ART WARE—THE LATEST STAGE IN CERAMICS

It has been said that the best English pottery is made of the dust of mountains and of animals. That is in a sense true, for the china clay which forms the most indispensable ingredient in the making of the paste for porcelain is a deposit from the worn and ground granitic masses of the immeasurable past, and it is mixed in this country with calcined bones. This bone-mixture was for a time a distinctive feature of English manufacture, but has been

largely imitated in other parts of the world. Who invented it does not seem to be known, but for generations every likely and unlikely ingredient was tried in the mixing-tank and the kiln, and much advance arose from accidental discovery. A feature of the industrial warfare of the past was the struggle between the west and the south-west for privileges in porcelain-making.

The Important Discovery of the China Clay Deposits in Cornwall

William Cookworthy, an inhabitant of Plymouth, a Quaker apothecary, set himself to find the best English earth for porcelain-making, after reading Père d'Entrecolles' letters about the Chinese industry, and in the end he discovered the china clay deposits of Cornwall. After twenty years of experiments he began the manufacture of hard porcelain, but eventually sold his patent rights to Champion, of Bristol. The Staffordshire potters at once leased some clay-mines in Cornwall, and opposed the renewal of Champion's patent for fourteen years. The two parties petitioned Parliament, and Wedgwood urged that "the natural productions of the soil ought to be the right of all," and that there should be "a free use of the raw materials that are the natural products of the country." Champion replied to the effect that he did not object to the use of the raw materials of Cornwall, so long as only Staffordshire earthenware was made from them, and not porcelain, and this was the view taken by Parliament. The manufacture of porcelain was left as Champion's monopoly. The effect was unexpected. The Staffordshire potters proceeded to imitate porcelain and compete with it; and an enormous development of the Staffordshire potteries followed, with a production of work of such taste and delicacy that for trade purposes it destroyed the border-line between earthenware and porcelain, and left the word "earthenware" a misnomer where the more artistic products of the Pottery region were concerned.

How the Potter's Industry Has Helped the Sanitary Reformer

From the earliest times the products of the potter's art have been of two distinct kinds —they have ministered to men's convenience in practical ways, or to his sentiment and taste. It is the same to-day, with great developments in each direction, but chiefly in the direction of utility. The ancient usefulness of the potter's wares took almost exclusively the form of storage. Liquids or food were kept safe in the family jars. That usefulness has been greatly extended in modern times. The glazed drain-pipe, for example, is the stand-by of the health reformer. The potter, indeed, has taken possession with increasing confidence wherever disease may find a lurking-place. In all sanitary proposals the first word is with the maker of clean glaze tiles that will wash down and retain no infection. We are on the way to having our houses cased with pot linings. The kitchens have already been annexed.

Then the range of earthenware vessels in ordinary use has been vastly extended. The number of "pieces" on the shelves of a modest house counts into hundreds. The common number for a full dinner-service is six dozen, and working-class folks with self-respect must have their dinner-service and one or two tea-services. There are bedroom-sets and breakfast-sets, and coffee-sets, and afternoon tea-sets, and dressing-table sets, with new accessories and designs tempting the tasteful. In cookery, too, fire-resisting crockery has won new ground.

The Objects of Art that Enter Both Cottage and Castle

Along the whole range of utility that borders on taste, and promotes the amenities of life, the art of the potter is more frequently requisitioned. No feature of our modern life tells the story of its advance in comfort more clearly than the growth of the pottery trade, which has changed an agglomeration of towns into one of the great towns of the kingdom—Stoke.

Whether equal advance has been made in the region of pure taste and artistry may be questioned. It is true that the potter has turned his back on the appalling monstrosities that were once thought to be decorations —the pot gods of the cottage mantelpiece —and a true conception of harmony in colour and grace in form is prevalent, but it may be doubted if anywhere in the world the art of the potter is excelling in delicacy and charm the productions of five hundred, a thousand, two thousand years ago. We buy or sell in this country eight million pounds' worth a year of bakings from the potter's kiln, but if we want fineness in conception or choiceness in workmanship we make our first search in the past. No doubt to-day there is more artistry at less cost, but not finer artistry at any cost, for it may be doubted whether the sense of taste has developed commensurately with man's progress on commercial, intellectual, and moral lines.

GROWING COTTON FOR LANCASHIRE'S MILLS

HOEING YOUNG COTTON IN THE SOUTHERN STATES OF NORTH AMERICA

WEIGHING THE DAY'S PICKING ON THE COTTON PLANTATION

The cotton industry is a remarkable example of the value of commerce. Cotton is grown in America and brought thousands of miles to Lancashire, where it is manufactured for all the world.

OUR COMMERCE OVERSEA

The Stupendous Interchange of Indispensable Products Between Country and Country if Manufactures are to be Sustained

HOW THE USE OF CAPITAL IS PAID FOR

OVERSEA trade is indispensable to the people of the United Kingdom. It is difficult to exaggerate its importance. Our home trade and our export trade are inextricably commingled, and their interdependence is so intimate and so far-reaching that it is impossible to understand the one without considering it in its relation to the other. The first object of the nation's work, as we have already said, is to put plenty at the disposal of the British population, but that object, which is at the root of home trade, cannot be achieved without the assistance of oversea trade.

The first object of the British boot trade is to put boots on British feet. But what are the boots made of? Inquiry shows that their chief material, leather, cannot be secured in sufficient plenty and variety without obtaining animal products from abroad. And that is but the beginning of the inquiry. Boots are made by machinery, and machinery is made of iron, steel, and other metals. As we have already seen, we have to import enormous quantities of iron and other ores, because of our own poverty in these materials. Consequently, ore won by foreign trade from Spain plays its part in making the boots turned out in a British factory, while copper from the United States and zinc from Germany have to be won by commerce, in order to make the brass eyelets which are necessary parts of a boot.

Therefore, when we see such a statement as that "the importance of our foreign trade is often exaggerated," or that "when a pair of British hands have made a pair of shoes, we should all prefer to see them worn on a pair of British feet," we know that the writer has no conception of the fundamental dependence of British home trade upon British foreign trade. British hands could not make a sufficient quantity of British boots without recourse to oversea supplies; and if the work of the British boot manufacturer is to go on, he must either himself find customers abroad for part of his output, in order to obtain the necessary foreign supplies of materials, or else the manufacturers in some other British industry must be exporting in order to obtain for the country, by exchange, what the country lacks.

Similarly, the first object of the British straw hat trade is to put hats on British heads. Inquiry shows, however, that the hatmaker's materials are almost entirely derived from oversea, and that without them British hands would not be able to make hats at all at competitive prices, and would merely be able to produce a very limited number of clumsy, heavy, and uncomfortable hats, made out of home-grown straw. Therefore, either the British hatmaker must find customers abroad, or some other trades must find customers abroad, in order that the home trade in hats may go on.

Important as these considerations are to all countries, they are especially important to the United Kingdom. There is no country under modern conditions independent of foreign trade. Even the United States, which, as we have already seen, is a hundred times richer than the United Kingdom in native materials, finds it necessary or convenient to import huge quantities of foreign produce. In the year 1910 the United States imported £108,000,000 worth of articles officially described as "crude materials for use in manufacturing," and, in addition, £57,000,000 worth of articles officially classified as "manufactures for further use in manufacturing." These are imports by a nation whose territory covers over three million square miles, ranging from 25 deg. North latitude to nearly as far North as the fiftieth parallel, with a climate

of such wide variation as to enable her to grow all but tropical products, and with mines of unsurpassed richness.

While such a nation finds it profitable to carry on foreign trade, to Britain commerce with the world is the first necessity of national existence. The world, as a whole, would be the poorer without commerce, but the United Kingdom as a Power would perish without commerce. If we can imagine an embargo placed upon her oversea transactions, her population would rapidly dwindle to one-fifth of its present total, or even less. From being a Great Power, Britain would fall to the scale of one of the least of the Minor Powers of Europe, with a small population primitively employed.

The circumstances being what they are, we need not be surprised that our examination of British production, conducted in the last chapter, reveals that a very large proportion of our productive workers work for export. They needs must, for, if they did not, their own work and the work of others who do not export would be brought to a standstill. The foreign and Colonial supplies must be obtained; the imports must be won and shipped home.

Three-Fifths of the Working Time of British Engineers Spent in Supplying Oversea Customers

While a larger number of our productive industries engage to some extent in export trade, and ship to places oversea a certain proportion of their outputs, some of our industries are chiefly devoted to the export trade, and find in the home market a minor call on their activities.

Engineering, for example, is one of the most characteristic of British industries. Its total gross output in a year is worth over one hundred million sterling. In 1907 it produced, the census shows, nearly £38,000,000 worth of machinery. The Custom House returns show that the exports of machinery in 1907 reached nearly £23,000,000, so that about 60 per cent. of the machinery which we make is sent abroad. To put it in another way, only about 40 per cent. of the men who make machinery in this country work for the home market. Very literally in this respect is the United Kingdom a workshop for the world. We see, in effect, the machines which we know how to make so well going out in order to bring back to us in exchange the many products which Nature has denied us.

More remarkable still is the case of the Lancashire cotton trade, one of the chief of our staple trades. We saw in the last chapter that the gross output of our cotton factories in 1907 was nearly £177,000,000. This figure involves an element of duplication, since the weavers made their returns inclusive of the yarn bought from the spinners, the value of which is also returned by the spinners, and therefore counted twice in the total. The output of the trade as a whole in 1907, eliminating this element of duplication, was about £120,000,000.

Three-Fourths of the Working Time of the Cotton Operative Spent in Supplying Oversea Customers

When we refer to the Custom House returns, we find that in 1907 we exported over £96,000,000 worth of Lancashire cotton goods. That is to say, we actually *exported 80 per cent. of the entire output of the trade.* We have to realise that eight out of every ten of the 572,869 persons who were returned as working in our cotton mills and factories are working for the export market, and that, therefore, if the Lancashire trade were reduced to working for the home market, it would, in view of the present extent of the home demand, be ruined. A well-known Lancashire man, a friend of the present writer, has put the thing in a nutshell thus: Let us imagine the days of the week divided up amongst Lancashire's customers. On Monday the British cotton trade works for the home market, with an hour or two to spare for the Colonies. On the first two or three hours of Tuesday it works for the Colonies. For the remainder of Tuesday until, say, three o'clock on Wednesday, it works for India. For the remainder of the week, until Saturday closing time, it works for foreign markets.

More than Half the Time of Woollen Workers Spent in Supplying Oversea Customers

How necessary is this gigantic export for the cotton trade! The cotton itself is an exotic product, which we needs must get from places of a certain latitude. In 1907 we actually imported over £60,000,000 worth of raw cotton. Without it nearly 600,000 people would be deprived of employment, and driven out of the United Kingdom, by irresistible economic pressure, to seek work where it could be found.

The case of the woollen trade is almost as wonderful. In our woollen and worsted factories over a quarter of a million of our productive workers find employment. In 1907, according to the Census of Production, the gross factory value of their output was worth over £70,000,000 sterling. This includes some duplication of values, but probably the output of the trade,

considered as a whole, was worth not less than £60,000,000. In the same year, our exports of woollens and worsteds were worth over £34,000,000, so that more than one-half of the production was made for export markets. Here, again, is a trade in which there is a great dependence upon foreign material. We import over £20,000,000 worth of foreign and Colonial wool every year, and this has got to be paid for either by exporting the manufactured produce of this trade or other trades, or by performing shipping or financial services for persons oversea. Broadly, we may picture such cases as it is wanted; and even in regard to such things as furniture, tastes in different countries vary so much that there is but a small amount of international trade in them. In 1910, while we imported an enormous quantity of wood, we exported less than two million pounds' worth of wood manufactures. Here we see clearly that the wood which we need has to be earned from abroad by trades other than those which use wood; and the same considerations apply to a number of other important materials.

And it is not merely materials for industry which have to be considered. A

UNLOADING THE WORLD'S WEALTH IN THE HEART OF THE WORLD'S GREATEST CITY

the machinery, cotton, and woollen industries as paying for their own imports of materials by work done upon imported materials for the export market. There are other trades which are inherently unable to do this. Take, for example, the trades which work upon wood. Nearly all the wood used in the United Kingdom has to be imported. In 1910 the imports for home consumption were worth £25,000,000. It is not possible, however, to build up much of an export trade in manufactures of wood, for a large part of all woodwork must necessarily be done in the country where

very large quantity of food has to be brought in. For the raw material of men themselves we have largely to look to the earning of food imports from abroad by work done in our export trade.

Let us now consider our external trade as a whole. Fortunately, there is no difficulty whatever in measuring and examining that part of it which is concerned with material productions—food, materials, or manufactures. Goods which pass over a political boundary line are checked and recorded at Custom Houses, and so we get for each country a usually reliable account

of its external dealings. In the case of the United Kingdom, the Custom House figures are, perhaps, a degree more reliable than those of most other countries, because, as British import duties are restricted to very few articles, there is no incentive to the under-valuation of imports in order to escape duties.

We give a broad statement of United Kingdom imports and exports, derived from the official records, on page 997. It may be termed a bird's-eye view of British oversea commerce as a whole. The main branches of trade are distinguished both for imports and for exports, and broad classification is made by great classes under the divisions 1. Food, drink, and tobacco; 2. Raw materials; 3. Manufactures.

The Value of Our Imports per Head of the Population

The meaning of the four columns of figures should be clearly understood. It will be seen that under imports three columns are given, headed respectively A, B, and C. Column A represents Total Imports, as received into the United Kingdom ports from all parts of the world, whether foreign countries or British.

The greater part of these imports is consumed in the United Kingdom, but we have a large entrepôt trade in imported produce, and some part of the total imports is re-exported in the merchant trade. This part is faithfully recorded by the Customs authorities, and we state it in column B, which is headed, "Re-exports of Imported Goods." It will be seen that the total of column A is £678,440,173, while column B amounts to £103,776,104. The next column, C, arrives at "Net Imports for Home Use" by the deduction of column B from column A, and we see that in 1910 the net imports into the United Kingdom for home use therefore amounted to £574,664,069.

We may perhaps better realise this figure if we bear in mind that, as we had in 1910 nearly forty-five millions of people, our imports in that year were worth nearly £13 for each man, woman, and child.

The Differences Between the Inward and Outward Shipments

The exports of British produce and manufactures are shown in column D, the total of which is £430,589,811. It is by comparing column C, "Net Imports for Home Use," with column D, "Exports of British Goods Only," that we make a true comparison of British imports and British exports.

With this chart of our commerce before us we can appreciate fully the fundamental differences between our inward and our outward shipments.

The first group, "Food, Drink, and Tobacco," shows a very large figure for imports, and a very small figure for exports. Of the kinds of food which we actually can grow in this country we import a great quantity, but a quantity probably not so large as we raise ourselves. It is generally thought that by far the greater part of our food comes from abroad. This popular conception is an error which arises from the fact that we do import by far the greater part of the *corn* which we need. With regard to meat, we are about equally fed by home and oversea supplies. There are, of course, many foods—such as Indian corn, rice, tea, etc.—which we cannot raise at all; and the imports of these, added to the imports of supplementary supplies of such foods as we can grow, raises the total importation of food for home consumption to a figure some £50,000,000 in excess of the value of British agricultural produce. On the export side, the figures, small as they are, relate very largely to manufactured foods. The total is almost negligible as compared with that relating to imports.

The Great Group of Raw Materials Coming Into the British Isles

The second great group, "Raw Materials," is necessarily a somewhat arbitrary classification. Nothing is more difficult than to draw the line between a raw material and a manufactured article. The Board of Trade, in arranging the classification shown in the table, grouped under "Raw Materials" articles of a crude character or products mainly manufactured. It is, of course, difficult to say whether such a material as the wood pulp used by papermakers ought to be classed as a raw material or as a manufactured article. The Board of Trade decided to put it in the raw materials group. Even if we take such an elementary product as our cotton imports, the cotton has been ginned, or cleaned of seeds, before it is exported. Coal, again, it might be urged, is a manufactured article to the coal-miner, for it has to be got with infinite labour. Some 80 per cent. of the value of coal at the pit's mouth is accounted for by wages. Nevertheless, the description "Raw Materials" will be generally understood to apply to products worked upon in bulk, and destined to receive a higher degree of finish before passing to the consumer.

CLASS OF GOODS	IMPORTS			D EXPORTS
	A Total Imports	B Re-Exports of Imported Goods	C Net Imports for Home Use	British Goods only
	£	£	£	£
1. Food, Drink, and Tobacco				
A. Grain and Flour	77,298,365	1,464,870	75,833,495	3,417,546
B. Meat	48,879,065	814,834	48,064,231	937,821
C. Other Food and Drink				
1 Non-Dutiable	72,254,717	4,483,726	67,770,991	19,715,338
2. Dutiable	54,731,583	5,846,723	48,884,860	—
D. Tobacco	4,624,686	267,728	4,356,958	2,042,678
TOTAL FOOD	257,788,416	12,877,881	244,910,535	26,113,383
2. Raw Materials				
A. Coal	34,119	321	33,798	37,812,573
B. Iron Ore and Scrap	6,261,272	11,737	6,249,535	478,171
C. Other Ores	8,973,522	546,902	8,426,620	72,036
D. Timber	26,198,854	814,017	25,384,837	128,794
E. Cotton	71,716,808	9,809,981	61,906,827	—
F. Wool	37,362,789	14,628,164	22,734,625	4,219,746
G. Other Textile Materials	12,802,002	2,867,368	9,934,634	323,818
H. Oil Seeds, Oils, etc.	37,587,030	7,376,942	30,210,088	5,030,215
I. Hides and Skins	12,881,066	7,090,376	5,790,690	1,758,277
J. Papermakers' Materials	4,973,444	188,405	4,785,039	743,869
K. Miscellaneous	42,451,126	19,975,385	22,475,741	2,769,852
TOTAL MATERIALS	261,242,032	63,309,598	197,932,434	53,337,351
3. Manufactures				
A. Iron and Steel	9,093,795	325,014	8,768,781	43,002,937
B. Other Metals	24,699,531	7,345,793	17,353,738	10,300,159
C. Cutlery, Hardware, Implements	4,673,888	746,470	3,927,418	6,424,002
D. Electrical Goods	1,686,469	205,167	1,481,302	4,117,840
E. Machinery	4,471,303	943,643	3,527,660	29,296,721
F. New Ships	27,104	1,762	25,342	8,769,331
G. Wood Manufactures	2,338,470	246,960	2,091,510	1,832,647
H. Textiles				
1. Cotton	10,874,620	2,374,825	8,499,795	105,915,626
2. Wool	9,599,281	1,181,429	8,417,852	37,524,473
3. Silk	13,521,001	1,965,690	11,555,311	2,276,956
4. Other Textiles	8,055,571	2,685,688	5,369,883	13,484,146
I. Apparel	4,433,477	819,566	3,613,911	9,686,792
J. Chemicals, Drugs, etc.	11,259,716	1,940,473	9,319,243	18,571,989
K. Leather and Leather Goods	12,499,423	2,258,867	10,240,556	7,718,588
L. Earthenware, Glass	3,817,405	205,602	3,611,803	4,349,109
M. Paper	6,413,704	232,302	6,181,402	3,118,573
N. Railway Cars, Cycles, Motors	5,606,679	574,040	5,032,639	7,453,329
O. Miscellaneous	23,784,176	3,300,664	20,483,512	29,120,068
TOTAL MANUFACTURES	156,855,613	27,353,955	129,501,658	343,023,286
4. Miscellaneous	2,554,112	234,670	2,319,442	8,115,791
GRAND TOTALS	£678,440,173	£103,776,104	£574,664,069	£430,589,811

In 1910 the net imports of raw materials were worth nearly two hundred million pounds, whereas the exports of a similar character were worth little more than fifty million pounds. Of the exports, the greater part consists of coal, the economic importance of which is explained in Chapter III. The enormous quantities of ores, timber, textiles, fibres, oils, hides, etc., brought in will not surprise those who realise how great are our national deficiencies in these things.

An exceedingly interesting point about the Raw Materials group is the great entrepôt trade which is done in them in the United Kingdom. Take wool, for example. We see that over £37,000,000 worth was imported in 1909–1910, and that nearly £15,000,000 worth was re-exported again

THE TOILERS BY THE SEA—UNLOADING A GIANT STEAMER AT LIVERPOOL DOCKS

THIS VIVID REPRESENTATION OF THE STRESS OF LIFE AT ONE OF THE WORLD'S GREATEST SEAPORTS IS FROM THE PAINTING BY A NOTABLE FRENCH ARTIST, VICTOR TARDIEU

in the merchant trade. That is to say, wool is brought to the United Kingdom from Australasia and other places, and a great wool market established here from which supplies are drawn by other European nations. Britain, indeed, is in regard to many products the *best European market for many things which she does not herself produce,* and her shipowners, her bankers, and her merchants gain large profits by this storehouse trade.

The Manufactures that Come Into and Go Out of the British Isles

Our imports of raw materials are thus four times as great as our exports, but the position is very different when we come to examine Group 3, "Manufactures." Here, it will be seen, the imports for home consumption in 1910 amounted to just over £129,000,000, while the exports of British manufactures were worth £343,000,000. The exports were thus two and a half to three times as great as the imports. It is a remarkable fact that about two-thirds of our exports of manufactures are made by four branches of trade—iron and steel, machinery, cottons, and woollens.

A very large part of the imports of manufactures consists of manufacturers' materials or supplies in a more or less finished state. For example, the item B. "Other Metals," shows over £17,000,000 worth imported for home consumption. What are these "Other Metals"? They consist largely of crude copper, zinc, and tin, which are, of course, fully as much raw materials as many of the articles so classified. It is equally true that the £10,000,000 worth of British exports under "Other Metals" consists of materials of industry exported to other countries. Similar considerations apply to item J., "Chemicals, Drugs, etc.," of which the net imports for consumption were about nine millions, and the exports of British make about eighteen millions. Chemicals are amongst the most valuable and indispensable materials of productive industry.

The Things Made by Our Workers with which We Buy Food and Raw Materials

The imports and exports of machinery are of great interest; it will be seen that there is a small importation of special machinery, but that we play a much greater part in equipping oversea manufacturers than is played by foreign engineers in the United Kingdom. With regard to textiles, British supremacy in cotton and wool seems unchallengeable, but in silk our imports form the greater part of our consumption. Generally, while manufactures form about 20 per cent. of our imports, they form about 80 per cent. of our exports. We see how a large part of the labour of our productive workers is exerted to create manufactured goods for export, and how the nation brings in in exchange enormous quantities of food, of raw and partly manufactured materials, and of finished articles.

The import and export table relates to merchandise only, but it by no means exhibits the whole of our oversea transactions. In the first place, we have certain imports of bullion and specie. As has been already explained in this work, by far the greater part of our oversea trade is conducted by means of bills of exchange, which are symbols for the goods to which they relate. It is only necessary to remit gold when there is a shortage of the paper instrument of credit. Our imports and exports of gold and silver are therefore insignificant when compared with our imports and exports of merchandise, as will be seen from the following facts.

The Gigantic World-Business Carried on with Very Little Gold

The table on page 1001 shows that in 1910 our commerce in merchandise was valued as follows, in round figures:

Total imports of goods.. ..	£678,000,000
Exports of imported goods ..	104,000,000
Exports of British goods ..	431,000,000
Total commerce ..	£1,213,000,000

If, therefore, gold had to be shipped across the sea in payment for every transaction, there would be transhipments of gold to this enormous value of £1,213,000,000, but the actual imports and exports of gold are comparatively trifling. In 1910, it is shown by the official Custom House returns, the imports of gold and silver, in bullion and specie, amounted to £71,400,000, and the exports to £64,400,000. We see with how little recourse to shipments of the precious metals it is possible in practice to carry on our gigantic oversea trade. What in effect takes place is a bartering of imports for exports—a bartering facilitated by that useful document the bill of exchange.

But our survey of British external trade is not yet completed. As is clearly brought out by the above figures (and as is the case every year), our imports of merchandise in 1910 considerably exceeded our exports, the former exceeding the latter by over

£140,000,000. We have just seen, too, that in 1910 (and this also is usually the case) our imports of the precious metals exceeded our exports. How, then, is the balance of imports accounted for? It is clear that the foreigners and British colonists who send us imports require to be paid for them. How is the balance settled?

The general explanation of the excess of British imports has been given in these pages in passing. It has been pointed out that we do work for persons abroad, not only by sending them material commodities, but by rendering them services which call for payment, which payment can only be made in imports receivable here, and over and above the imports which are due to us because we sent out goods are the imports which are due to us because we render services. For these, Sir Robert Giffen coined the happy phrase "Invisible Exports."

The Vast World-Commerce Carried About in British Ships

The first of these services is the very important work which we do for the world at large as sea-carriers. About one-half of all the world's sea-going ships—we shall have occasion to go into the facts in more detail hereafter—belong to the United Kingdom. This fact has an extraordinary significance. *It means that about one-half of all the world's sea-borne commerce is carried in British holds.* How are the freights, etc., earned by these ships, received in this country? The answer is that they are payable, just as export earnings are payable, in imports receivable. It is impossible to calculate precisely what these shipping earnings receivable are worth, but the amount is certainly as much as £100,000,000; and £110,000,000 is a conservative estimate for the year 1910.

The second great category of services rendered by British citizens to persons abroad is the investment of British capital. British investments in the British Empire and in foreign countries have reached enormous dimensions, and every year a great sum is receivable by this country in payment of interest.

How We Get the Interest on British Capital Invested Abroad

This interest, if drawn by those to whom it is due, reaches the United Kingdom in the form of imports. For example, British capitalists have established tea-gardens in Ceylon. The interest which becomes due from the capital so invested is drawn into the United Kingdom in the form of tea, the produce of the investment.

Again, British capitalists have invested a large sum of money to set up rubber plantations in tropical countries. The interest on these rubber investments is drawn into the country in the form of the valuable raw material the investment was made to produce. Another typical case is the British investment in Argentine railways, the interest receivable on which is drawn into this country in the shape of Argentine corn, wood, or meat; and it will be perceived that such imports are recorded on the import side of the returns, while, of course, there is no corresponding entry on the export side.

Many attempts have been made to calculate the amount of British investments in places oversea. One of the best of these is that made by Mr. George Paish in a paper read to the Royal Statistical Society at the end of 1910. He submitted figures which are summarised briefly in this statement.

OVERSEA INVESTMENTS OF THE UNITED KINGDOM

PLACE OF INVESTMENT	AMOUNT
WITHIN THE BRITISH EMPIRE	
Canada and Newfoundland	£372,500,000
Australia	301,500,000
New Zealand	78,500,000
S. Africa	351,400,000
India and Ceylon	365,400,000
Other places	84,700,000
TOTAL BRITISH POSSESSIONS	£1,554,000,000
IN FOREIGN COUNTRIES	
United States	£688,000,000
Argentina	269,800,000
Brazil	94,400,000
Mexico	87,300,000
Japan	53,700,000
Chili	46,400,000
Russia	38,400,000
Egypt	43,700,000
Other places	316,300,000
TOTAL FOREIGN COUNTRIES	£1,638,000,000
GRAND TOTAL ..	£3,192,000,000

This table shows how great is the British lien upon the world. Here is a sum of over three thousand million pounds invested, approximately as to one-half within the British Empire, and as to the other half in foreign countries. Apart from the Imperial investments, the main bulk of the capital has been placed in the United States and South America. The extraordinary strides made by the South American nations in recent years is largely due to the assistance given by British capitalists. If we regard this British investment abroad by continents

we find that the American continent as a whole has 53 per cent.; Asia, 16 per cent.; Africa, 14 per cent.; Australasia, 12 per cent.; and Europe only 5 per cent. Canada figures most largely in the Imperial list, and the United States in the foreign list. Argentina has been developed by nearly £270,000,000 worth of British capital, and Brazil and Mexico have had each nearly a hundred million pounds.

Generally, the bulk of the investments have been made in "new" lands which cry aloud for the application of capital to their virgin resources, and which usually offer a higher rate of interest than is current in old and developed regions.

The £250,000,000 Worth of Things that Britain Calls Upon the World to Give Her

If we assume that this capital returns only 4 per cent. on the average, then over £120,000,000 per annum is receivable in respect of it. Probably, however, the average rate of interest is greater than this, and £150,000,000 is by no means a liberal estimate of the interest receivable in the United Kingdom.

There are minor "invisible exports" which need not detain us. We may set them off against the fact that there is a certain amount of services rendered by persons abroad to this country. Foreign ships sometimes carry British goods, and foreign investors sometimes hold British securities. It is quite certain, however, that these considerations are negligible in relation to the enormous total of the invisible exports.

We now realise that, taking the shipping services to be worth no more than £110,000,000 per annum, and assuming that the interest receivable from abroad to be no more than £150,000,000 per annum—both figures are exceedingly conservative—British visible and invisible exports together amount to a very handsome sum, visible exports amounting to 535 millions and invisible exports amounting to 260 millions, making 795 millions. Bringing all the facts together, we obtain the nearly complete record of imports and exports shown in the table on this page.

It will be seen that, with the addition of the important invisible exports, the British exports in 1910 were worth at least £859,000,000. On the other hand, the imports actually received in this country amounted to about £749,000,000. This, in its turn, calls for explanation, and the explanation is a simple one. The meaning of this result is that in 1910 the United Kingdom *did not draw from abroad all the imports that were due and payable to it.* Over £100,000,000 was left abroad, and re-invested there, to make an addition to the British lien upon the world. It is a marvellous fact that, *quite apart from the exportation of merchandise,* British ships and British oversea investments together give us a call upon the world at large for over £250,000,000 worth of imports per annum. The United Kingdom is the greatest creditor nation.

THE GRAND TOTAL OF BRITISH COMMERCE IN 1910

IMPORTS		EXPORTS	
Visible Imports		**Visible Exports**	
Merchandise	£678,000,000	Merchandise	£535,000,000
Bullion and Specie	71,000,000	Bullion and Specie	64,000,000
		Invisible Exports	
		Service of Ships	110,000,000
		Interest due on Capital invested abroad	150,000,000
TOTAL	£749,000,000 +	TOTAL	£859,000,000 +

+ The plus sign is added to remind the reader that the totals, large as they are, are not quite complete

Such are the broad outlines of the external commerce of the first among trading nations. It is far easier to set down the vast values dealt in than to grasp the great part which they play in the world.

Why Should There be Any Poverty in a Prosperous Country?

The thoughtful student of affairs may very well ask himself why with a commerce of such extent there should remain poverty in the United Kingdom. It should be borne in mind, however, how great also is the number of people who live by this commerce. As we have already pointed out as a cardinal feature of the case, the maintenance of forty-five millions of people in the British Isles is an artificial thing, which depends primarily upon a great source of power with which to create a manufacturing industry, and secondarily upon the magnification of the use and value of that power by the fructifying arts of commerce.

JAMES WATT'S FIRST EXPERIMENT WITH THE STEAMING KETTLE

HOW THE IDEA OF THE STOCKING-LOOM CAME TO WILLIAM LEE

The woman problem in industry may be said to date from the introduction of machinery and steam power, which drove manufacturing processes from the home and led to the modern factory system.

THE FUTURE OF WOMAN

Why Modern Woman is Discontented, and How Far Her Demands Conflict with the Interests of the Race

SHOULD MARRIED WOMEN EARN A LIVING?

THE woman of the future will be the child of the woman of the present. If she takes after her mother, she will be a strange problem.

For the woman of the Anglo-Saxon races seems now to have much in common with the Sphinx. She has set the men of her race a riddle which is very difficult to grasp, and uncommonly hard to solve. For about five hundred thousand years there has prevailed a division of labour between the sexes. The kinds of work divided among men and women have, of course, often changed with the change of economic conditions, but the sex division of activities has ever persisted. In practice it has worked out fairly well. By means of it, mankind has conquered all its foes and peopled the greater part of the earth, and arrived at a very promising position for obtaining the mastery over many forces of Nature.

Now, however, woman says she has been robbed of her special duties, and she intends, it appears, to compete generally with man. The trouble began when James Watt invented the steam-engine, and Hargreaves the spinning-jenny. The industries of civilised society were then built up on a new principle, and the occupation of the housewife was gone. From jam-making to knitting socks, from bread-baking to spinning thread, the hand labour of domestic industry gave way to machine work performed on a vast scale in factories and great commercial establishments. It became cheaper and easier to buy things at shops than to toil over making them at home.

Woman has now ceased to make the greater part of even her own clothes. Her spinning-wheel is broken, and in a thousand huge buildings the steam-driven loom produces the garments worn by half the world. Steam often shapes the bread she eats, and in many cases the loaves are set down at her door by a man in a motor-cart. If she is a well-to-do woman living in a modern city, her carpets are beaten, her windows cleaned, and her floors polished by machinery. Even the domestic sewing-machine, which supplanted the ancient needle, is beginning to be antiquated; for steam-engines are now driving in great factories the ingenious pieces of mechanism which make every article of woman's attire.

Millions of girls and women of the working classes have gone where work went—into the factories. Hundreds of thousands while away the time between girlhood and marriage with office-work and shop-work in the larger towns. Still greater numbers of poorer girls carry on much of the domestic work in the houses of the fairly well-to-do housewives. And a good many daughters of the merchant class and the professional class have found a new field of work by studying at hospitals and universities and becoming high-school teachers and nurses. Women have also entered some of the branches of the public service, as instructors in elementary schools and workers at various employments in the Post Office.

Yet still the modern woman cries to the men: "You have robbed me of all my domestic crafts, and left me in dull, wearisome idleness. I want more work to do." When a woman wants a thing, she usually gets it in the end. The profession of medicine is already opened to her. In the profession of literature she has distinguished herself from the days of Aphra Behn; and since the close of the eighteenth century she has probably written more works of fiction in England than male novelists have. She has won considerable power, direct and indirect, in local and Imperial politics; there

are many questions on which she can vote in regard to local affairs; and in Imperial politics there are many channels for her energies. Practically only the Law, the Church, and the Imperial Parliament are now closed to the British woman. Yet, if those who speak for her are to be believed, she is still raging with discontent, and eager to break the windows of tradespeople in order to assert her rights. Olive Schreiner's book on "Woman and Labour" is the latest re-statement of the point of view of the modern rebellious woman.

It would be idle to deny that any wide-spread discontent exists. It does exist, especially among the younger women of the educated classes. It is not merely a question of obtaining the right to vote for Parliament; the agitation over this matter is a symptom of a much deeper unrest. What many of the inspirers of the political movement aim at is an entire equality of labour between the sexes, instead of the old division of work between the man and the woman.

Should the Economic Independence of Woman be Encouraged or Combated?

"The economic independence of woman" is the battle-cry; and, in some countries and in some classes, the economic independence of woman is not now a theory; it is an accomplished fact. The only question is whether it should be encouraged or combated. Some countries are encouraging it: Japan, for instance, and Germany. The recent progress of the German woman worker is extraordinary. The returns show that, after making due allowance for the growth of the population of Germany, the proportion of female labour has increased by one-third in merely five years from 1905 to 1910. The general trend of the industrial civilisation that is spreading through the world makes for the economic independence of the woman of the working classes. She labours for a much smaller wage than the man, and thus enables manufacturers to reduce their costs, and compete with advantage against the owners of factories in which men are more largely employed.

The steam-engine has, in many cases, reduced the sexes to a condition of economic equality. In many modern processes of manufacture, the superior muscular power of the male is, in itself, of little use to him when competing with the woman worker. The machine does all the violent labour; and a skilful hand and a steady eye are often all that are required from the attendant on the iron slave. So woman comes in, and offers her services cheaply, and the man is underbid and defeated.

In Germany, for example, in 1910, there was an extraordinary increase in the amount of manufactures, the exports being nearly one thousand million marks more in value than the exports for the preceding year. With an expanding trade like this, the German working man should have been able to obtain an increase in his wages, to meet the continually rising cost of living. The new vast multitude of cheap women workers, however, is preventing him from forcing up his wages. He has either to buy less food for himself and his family, or to send his wife and daughters into the factory in order to help to meet the increased cost of living.

The Englishman's Love of the Position of Sole Bread-Winner in the Family

Of course, he is not buying less food; he is adopting the alternative. Our Lancashire weavers followed the same course when, with the advent of the steam-loom, their homes were disorganised. But the English working man does not like to see his wife and daughter compelled to wear themselves out with work in mill and factory. Not without a struggle does he give up his position as the sole bread-winner. In districts where rude labour is highly paid the British wage-earner tries to keep his wife and daughters in comfort at home. In some colliery districts, for instance, the proportion of unoccupied women between the ages of twenty-five and forty-five is 91·4. In mining districts generally the proportion is still fairly high.

Below these districts are the cities where the artisans send many of their girls out to earn their living in domestic service; and last and lowest of all come the towns where textile goods are manufactured. Here is found the largest proportion of women workers, both single and married. Out of every hundred women in our textile factories, about twenty-four are married and four are widows, and seventy-two are single women.

How Woman's Entry into the Manufacturing Industries Keeps Down Men's Wages

According to the last available figures, the women earn each week when working 15s. 5d., and the men 28s. 1d. On the other hand, in engineering, shipbuilding, and many metal trades, where men meet with little or no competition from women, their wages amount on an average to about 34s. a week. When a man earns £1 14s. a week, there

is no pressing need for his wife to neglect her home and toil all day long in factory or workshop. We have about a million and a half male workers in the engineering, shipbuilding, and metal trades whose average weekly earnings are about £1 14s. a week. Twenty years ago they had only about £1 7s. a week. Had it been possible to flood the labour market of their trades with cheap female hands, this striking increase in wages would not have taken place. Does it not look as though the economic independence of the working woman were obtained, in some cases, at the expense of the family?

Here we reach the central point in the modern problem of the re-division of labour between the sexes. It is wrong and mischievous to look at the matter either from the point of view of the man or from that of the woman. Neither of them is a real unit of the State. The family is the unit. This is the grand fact; and when we talk about one man one vote, or one woman one vote, one man so much wages, and one woman so much wages, the rights of the individual, and the wrongs of the individual, this grand fact becomes obscured by matters of much less importance. Certainly the family has been much altered as an institution in modern times, but it remains the unit of the State. The State has indeed had to pass many laws during the last century in order to keep the homes of many of the people in existence.

The Destruction of Family Life by Economic Wages till the Law Intervened

There was a time when a Royal Commission reported that over great portions of our country the parental instinct was wholly extinguished. This happened in 1842 and 1843, when the English working women were beginning seriously to compete with the English working man. They took their children with them into mill and factory and workshop. Little mites of the age of five, six, and seven were kept at work for fourteen hours a day in mines, calico-printing works, and lace-making works. In many other trades, the ordinary age was from eight to nine. This did not happen occasionally; it was almost general in our great industrial centres. The first result of the economic independence of the married woman was that the Government had to intervene to build up the family again.

A series of laws was passed, culminating in the Children's Act of 1908, which controlled the authority of the parents and gave the child a legal right to be well treated and cared for. The ages at which its education should begin and end were fixed; the age at which it could be forced to labour was defined; the hours in which it could be made to work in later childhood were strictly established. The child was protected from the cruelty and neglect of its parents; and, in short, it was given by law that position in the family which should be—and even in benighted, heathen, savage countries often is—assured to it by the natural impulse of parental love.

How the Home and the Children Suffer by the Work of the Wife Outside the Home

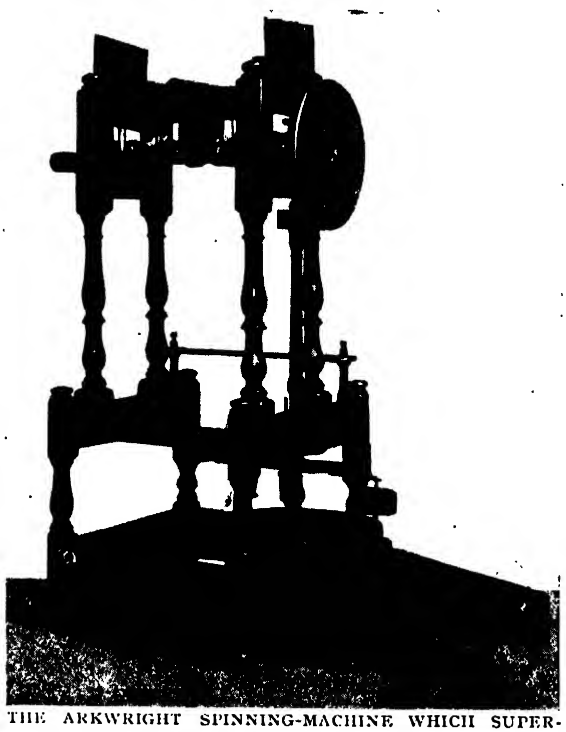
At the present day, in the large manufacturing towns of the North, where many married women of the working classes have won their way to a position of economic independence, the physical condition of their children is often deplorable. Hundreds of thousands of the future men and women of England suffer from disease and neglect. Their fathers may earn on an average 28s. 1d., and their mothers 15s. 5d., the eldest girl 8s. 11d., and the boys 10s. 5d. a week. That would make a very comfortable income for a working class family, even if the boy and girl were not of an age to be legally employable. Yet there can be little doubt that the family would be better off physically, mentally, and morally if all the paid work fell on the man, so that he was able to demand 34s. a week, like the men in the engineering, shipbuilding, and metal trades.

It is, of course, possible that the trades in which married women are now employed could not be carried on profitably in the face of foreign competition, if the wages of the men were raised to 34s. a week. There are, unfortunately, hundreds of thousands of other cases in which the husband earns so little that the wife is compelled, by sheer poverty, to desert her home, and labour for the few extra shillings which make the difference between a family life of enfeebling want and a family life of bare sufficiency.

The Natural Reversion of Woman to a Love for Work in Her Own Home

It is also probable that the women workers in mills and factories were driven by dire need from their homes when the industrial revolution started. All this, however, may prove in the end to be only a deplorable economic accident in our industrial history, if it does not lead to the general abolition of the assumed division of labour between the sexes.

Happily, a good many working married women, whose grandmothers won that economic independence for which some women of the middle class are now striving, are becoming discontented with their apparent victory. They are beginning to yearn for home life. Until quite recently, the factory, with its long hours of dull toil, had a strange fascination for them. The bustle, the excitement of working together in large numbers, and the pleasure of having an independent income were the chief attractions. At least, there were many cases in which factory life was not pursued for the sake of profit. For it appeared from the evidence of a Labour Commission that it was not at all uncommon for a married woman to pay almost as much as her wages to the caretaker who looked after the house and children. In some cases, married women actually paid away in this manner more than the weekly money they earned in the factory. No doubt, a large majority of factory hands laboured, not merely for an exchange of duties, but for actual subsistence; but it was exceedingly disquieting to find that there were considerable numbers of married women of the working class who deserted their homes, simply because they abhorred the task of looking after their own children and keeping the house clean and managing their domestic affairs. Married working women of this sort can still be found, but they are happily growing rarer.



THE ARKWRIGHT SPINNING-MACHINE WHICH SUPERSEDED THE "WOMAN'S WHEEL"

After long experience, they have seen that their husbands tend, more than other married men, to go to the bad. The absence of home life tells on the character of the man. Finding no tranquil, healthy, inspiring source of pleasure in the place where he and his wife, both dulled and fagged by the day's work, meet for supper, bed, and breakfast, he seeks in the public-house and the betting-den for some excitement that will make him forget that he has no home. In the end the woman finds she has purchased her economic independence at the price of her life's happiness and often of the welfare of her children. So she is now taking to giving up her factory life, and devoting herself to the fine womanly task of making a home for her husband and her little ones.

But while the women who have been for generations working shoulder to shoulder with the men in the industrial struggle are beginning to long for the quiet joys of family life, many of the women of the middle-classes are wildly and clamorously fighting for their economic freedom. On the whole, it cannot be said that there is a general economic pressure behind this new movement. The women are not starving in their homes, as the women of the lower classes were at the beginning of the nineteenth century when the steam-engine destroyed their means of livelihood. It is the hours of vacant idleness in many a middle-class home against which the revolting daughter revolts; against, perhaps in a large number of cases, the gentle but continual pressure of the mother's authority; against the apparent injustice of the customs and traditions which hinder her from completing her education in the rough but exciting school of life, and winning there, side by side with her brothers, the wisdom born of experience.

Besides this longing for personal freedom, there is sometimes a praiseworthy wish to help in contributing to the family expenses, or the less noble aim of earning enough money to buy the finer clothes and the little luxuries which the father of the family either cannot

afford to give the daughter or keeps from her on principle. The fact is that the movement of emancipation among the girls of the middle class arises from a concurrence of two forces: the progress of female education, and the insidious advance of that disease of civilisation—luxury. It is luxury that has produced in the middle-class home the lack of occupation which makes the modern girl fretful, fanciful, and impatient. There are sufficient household duties to keep the mother cheerfully busy and in touch with the realities of life, but the girl has often good reason to complain of the emptiness of her existence.

Marriage, of course, is the natural remedy; and if the modern girl were, like her great grandmother or grandmother, wedded before she was twenty, with children at her knees at twenty-five, her life would be full and real, and there would probably be no woman's movement now. The emotional, physical, and moral unrest among the women of the middle classes is part of the price we pay for the striking postponement of the age of marriage in these classes. Nearly all the burden falls on the young unmarried woman; and her cry for freedom is only a cry for other interests in life, in place of those which are being denied to her.

SIR RICHARD ARKWRIGHT, ONE OF THE GREAT INVENTORS OF FACTORY MACHINERY

These new interests the nation is now seriously attempting to provide by a new system of education. When, in 1848, Frederick Denison Maurice, with the help of Charles Kingsley and other men of the same school, opened Queen's College, there was a great deal of hostile comment from contemporary writers. Maurice, Kingsley, and their brother professors from King's College were, however, men with large and sound views, and the movement they founded has become of world-wide importance. They aimed at revolutionising the entire education of the girls of the middle classes, and they wisely began teaching the teachers as the first essential step in educational reform. Queen's College grew out of the Governesses' Benevolent Institution, and in it were trained many of the women who continued the work of Maurice. In 1869 Girton College was opened to women who desired the same kind of teaching as men obtained at Cambridge; and six years afterwards, Newnham College was established in the heart of Cambridge. In London, Frances Mary Buss brought a splendid talent for organisation to the task of infusing a new spirit into the high school system for girls. During the last forty years this system has done much to put sound instruction within the reach of a vast number of women who would otherwise have been left without any intellectual training of value.

All this education is progress—progress of a highly valuable kind. It does not benefit the women only—it benefits the race. A man no longer marries a cook and housekeeper; he marries a companion whose trained and furnished mind can be interested in all his higher interests. The especial quality of a woman the cultivated wife still retains—the quick emotional nature which supplies the deficiencies of the somewhat harder character of the man. Her ideas are still winged with feeling; she remains the heart of the home instead of attempting to usurp the intellectual headship. Her powers of sympathy, however, are stronger; they do not run to waste in sentimentalities, but are directed by knowledge and thought to their proper field of exercise.

Besides being a real companion to her husband, she is a better mother to her

children. Her boys' minds now do not, as they grow, become an unknown territory to her. While holding to them still by the power of her love, she can enter into everything that interests her sons, even as she enters into everything that interests her husband. In the same way she can accompany her daughters through every stage of their development. Wiser than her own mother in dealing with the new spirit of girlish unrest, she will be able to help the women of the next generation to pass more easily than she did over the long period between girlhood and marriage. Such, let us hope, will be the woman of the future, when she marries and settles down.

But will she marry? Here we arrive at the crux of the problem. Owing to the present disproportion in the number of the sexes, and to the postponement of the age of marriage, it is not possible for every woman to find a partner for life in this country. No doubt the balance of the sexes will be restored in due time, but this time may not be due for another century or more. Meanwhile, it has been calculated that the proportion of women in England and Wales who may be expected to remain unmarried is one in five in London, and one in six elsewhere. By far the greater number of the spinsters are compelled to work for a living. They will therefore continue to agitate for the economic independence of woman generally. Probably they will remain large enough in number, for many years to come, to affect for the worse the wages of men.

But the harm they are compelled to do in this direction may be balanced, to some extent, by the good they do in another way. There is a splendid field for them as organisers. It is clear that the young unmarried girl, who is destined to marry, will also maintain the economic freedom which has now been won for her. She will insist in continuing, in the world of labour and business, the education which she has begun in school. The only way in which the gap between her school life and her married life can be healthily filled is by letting her take an interest in every kind of work for which she is fitted. It is here that the industrial effect of a number of well-instructed, healthy-minded, vigorous permanent spinsters will be seen. A man's work is not interrupted by marriage; neither are his efforts slackened by the prospects of his marriage. On the contrary, both are intensified. In the case of women, however, the expectation of marriage has a considerable bearing on the question of wages; and it is found to make against all organised effort on their part, whether for improvement in their position or for provision against sickness and old age. So in the world of working women there must remain a considerable number of permanent spinsters to give continuity to the management of all the associations of women workers of every class.

JAMES WATT, ONE OF THE FOUNDERS OF FACTORY POWER

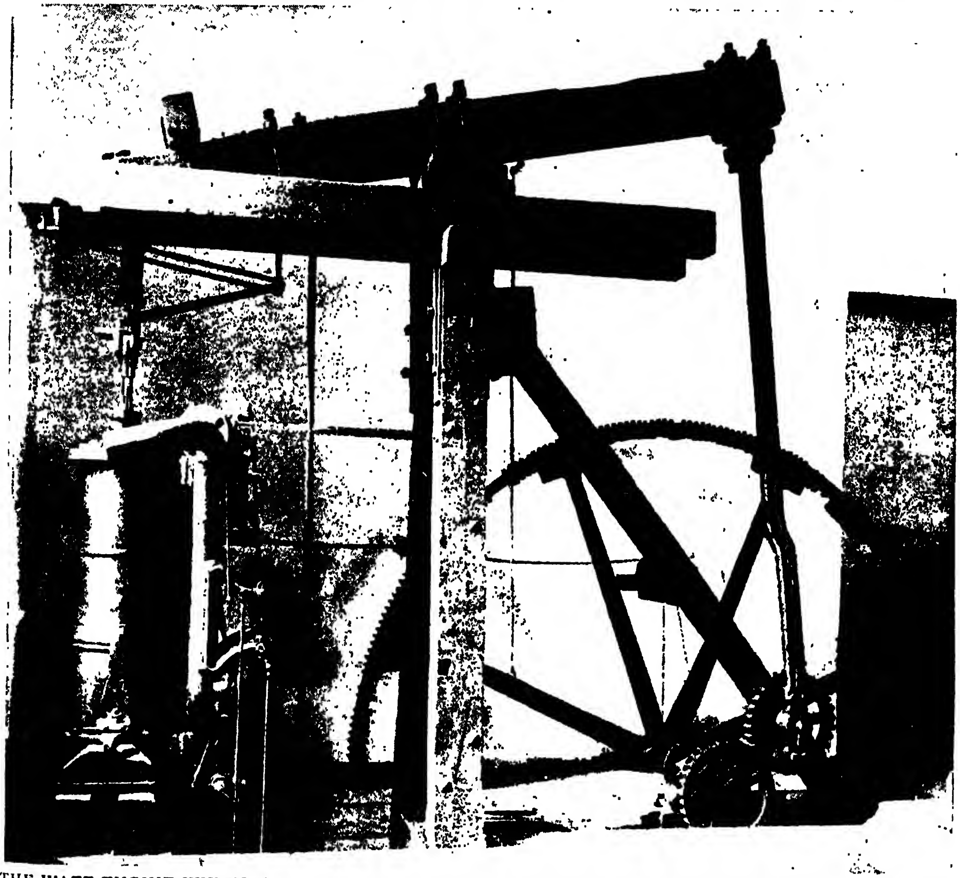
Such, at least, is our solution of one of the most difficult of all the social problems of Great Britain at the present day. If, however, the women of the middle classes — unwarned by the experience gained in a struggle of a hundred years by the women of the working classes — insist on carrying independence into married life, nothing but disaster will come of it. The position of a single man or a single woman is one thing; the position of a married woman is another thing. On her directly depends the future welfare of the race. She is governed by the needs of the family; and in the family at least there persists a natural division of labour. There are still sufficient household duties to occupy the entire working hours of a married woman's life, if she performs her natural function and brings up three or four healthy

children. The steam-engine and the modern organisation of industries may have robbed the housewife of some of her work; but it must be remembered, on the other hand, that the modern house is less simple than the houses in which our forefathers lived, and the general result is that the modern married woman of the working class, the shopkeeping class, and the middle class of moderate income can easily discover as much work to do in her home as she has time for.

This is especially the case where a wife is willing to save her husband's money by having the washing done at home, and economising in other laborious ways. We find it difficult, indeed, to see how a good housewife, whose husband is earning only the ordinary workman's wages, could make much time to take any active part in the political affairs of the nation. If, however, she can make time, she will certainly show that she needs more interest in life, and man will have to yield to her.

Our women have won, and won fairly, many rights that were once unjustly withheld from them. In some respects their position generally is higher than that of the men. They have a good deal of power, and are likely to gain still more in the immediate future. But if all that they have gained makes them less capable of being mothers and making homes, then the race must suffer. Already it seems as though the future of the highly cultivated and economically independent native white woman of the United States has been decided; she will have no future, because she will not exist. Votes do not decide everything, even where women have now obtained the suffrage. For what was decided very many millions of years ago among the Protozoa cannot, as Professor J. A. Thomson has said, be annulled by Act of Parliament. At least, if it is annulled, then the people of these islands will vanish.

The family must stand, however the individual man and woman live; the family must stand, and the life of the family must be efficient.



THE WATT ENGINE WHICH HELPED TO ESTABLISH STEAM POWER AND DISPLACE DOMESTIC LABOUR

'IT IS NOT LINEN YOU'RE WEARING OUT, BUT HUMAN CREATURES' LIVES'

THIS FINE PICTURE OF THE TERRIBLE SIDE OF WOMAN'S WORK IS FROM THE PAINTING BY C. CALTHROP

THE CRADLE & THE WORLD

How the World May Win Health Through a New Worship of Mother and Child

THE PRICELESS TREASURE OF INFANCY

THE word "infant" has a definite and important meaning in hygiene, as in law. In law an infant is a young person under twenty-one years of age. In hygiene an infant is a child from birth to the completion of its first year of life. We know that the child is really nine months old, or should be, at birth, and we shall never deal effectively with infant mortality until we remember that fact, but for convenience we may call infancy the first year of life. The definition is approximately accurate, more so than in the legal use, for an infant is literally a "not-speaking," and the first year of independent life does correspond more or less to the period before speech.

The question of speech, however, is not to the purpose of the hygienist or the Eugenist; and the utility of making this special recognition of the first year depends on deeper considerations. It is that the first year corresponds—roughly, of course, but still adequately—to a definite stage in the normal nurture of the child. That, at any rate, is the point of view from which we shall regard it here, though it may be that those who compile vital statistics, from the Registrar-General downwards, take the first year merely for its obvious convenience. For us, however, the first year is the period of breast-feeding, the period during which the child is a suckling, or nursling. Physiology has shown that during this period the child's digestive glands cannot digest starch—which is not present in any form of milk—though soon thereafter the capacity for starch-digestion appears. This indicates a real basis for our recognition of the infant, and it is of the utmost importance from the point of view of infant-feeding.

Doubtless most mothers give up breast-feeding at some such period as nine months, and doubtless many infants are not breast-fed at all. None the less important is it to know that they should be, for if we forget that we shall never solve the modern problem of infancy. As for the ordinary period of breast-feeding, it needs to be pointed out that there is no scientific basis for it. So far as can be ascertained, the only reason why doctors have recommended this period is by way of symmetry, when compared with the period of gestation or expectant motherhood. The idea seems to be that if gestation lasts nine months, lactation ought to last nine months also. It has long ago been shown, however, by comparative study of mankind, that the natural period of lactation is probably not less than two years, a period which is far exceeded—even up to three years and more—by many savage mothers. We must note also that the period of gestation and the subsequent period of lactation, as shown by mothers not affected by civilisation, are far and away longer in the cases of mankind than in the case of any other mammal—with the exception of the elephant, which is easily explained by its immense body-weight.

There is thus no basis whatever, in the laws of human physiology, for the nine months' period of lactation; and, on the other hand, it is the everyday fact that children of a year old, or younger, may be weaned with safety, if not with advantage. The one-year period is thus a very useful basis for study and observation, and we shall here accept it as approximately constituting the second stage of human nurture, or the first post-natal stage—the actually first stage, which is, of course, the most important of all, being the period immediately preceding birth.

By far the most conspicuous general fact of this period of human life is its enormous death-rate. Not until we reach the extreme upper limits of old age, and calculate the

death-rate of, say, nonagenarians, do we find death's harvest so abundant. This infant death-rate we commonly call the "infant (or "infantile") mortality." The general death-rate, like the birth-rate, is calculated per 1000 of population. An annual birth-rate of twenty-five, such as we may never see again in England, means the birth, in the year, of twenty-five (registered) babies for each thousand persons living.

The Different Ways of Calculating the Annual Birth-Rate and the Death-Rate

If the size of the population be inaccurately known, the birth-rate cannot be accurately stated, as we have just learnt in connection with the recent census, where some birth-rates had been under-estimated because the corresponding populations had been over-estimated. But the infant mortality rate is expressed otherwise, and is not open to the same risk of error, though it has abundant risks of its own. It is reckoned per thousand babies born (and registered, a most important qualification, when one knows what really happens). Thus if a thousand babies are born in the year, and a hundred die—not necessarily a hundred of those born, but a hundred under one year of age—the infant mortality rate for that year is one hundred. As to the ages of these babies, we soon find that they are more liable to die the younger they are. Especially in the first three months of their independent existence do they need most care, as we might expect. Thus most of the babies constituting the infant mortality in a given year will have been born in that year, but some will have been born in the preceding year.

The Special Dangers of the Life of Very Young Children

Very few people realise the precise character of these figures. Casual observers include any young child among infants; and very frequently indeed one sees proposals for, say, the care of two-year-olds, or children just before the school age, described as bearing on infant mortality.

We must realise that infant mortality has to do only with children less than a year old. The infant death-rate is by far the most important of all the constituents of the death-rate, amounting to about one-fourth of the whole. Thus a general death-rate of sixteen per thousand living may include an infant death-rate of four, so calculated; but as we describe infant mortality not per 1000 of the population, but per 1000 births, the figures in such a case will be much larger—say, 150 or 250 per thousand, as the case might be.

Until a few years ago, about one seventh of all the babies born in this country failed to complete a year of independent life. This meant an infant mortality of about 140 per thousand. The number of actual infant deaths in a year would thus be, in this country, somewhere about 120,000, out of between eight and nine hundred thousand births. The figure had remained very constant on the whole, for sixty years, ever since registration was enforced, and indeed had very slightly risen, while the general death-roll during that period, on the other hand, had very greatly fallen. This simple fact is evidently remarkable, clearly indicating that the factors which have produced the fall in the general death-rate do not bear adequately, or in any similar degree, upon the special dangers of this very special and distinctive period of life.

The Terrible Damaging of All the Life that is Lived in a Slum

All statements and figures in this matter, however, are entirely inadequate to express the real nature of the facts, and especially are they inadequate, as we shall see, when we come to meet the arguments of the "better-dead" school, now headed by Professor Karl Pearson, and several other writers who have not come into any kind of personal relation with the facts of infant life. The figures express the dead, but they take no account of the damaged.

This is the cardinal point, in virtue of which the first-hand students of infant mortality regard the statistical figure as merely a rough index of the amount of vital damage that is being done in any particular time or place. Of course, we are here dealing with an immensely complex phenomenon, as complex, indeed, as are the facts of death in later life. If all infant mortality were due, as a tiny proportion of it is, to the inflammable nature of cheap flannelette, plainly the number of deaths would indicate no more than deaths, though, even so, a number of babies would perhaps be burnt and damaged for life without being actually killed. If we take account of the chief causes of the mortality, and not least if we begin at the beginning, as we have sought to do in our study of expectant motherhood, we see at once that infant mortality bears no resemblance at all to the beneficent process of natural selection with which the Herodian school confound it.

We may accept Professor Patrick Geddes's division of Eugenists into the Herodians, followers of the method of Herod, and the Magians, followers of those Wise Men who

worshipped infancy. Any process of selection that can be justified must weed out the worthless without half destroying the worthy. Such is the action of natural selection. But to talk of natural selection in anything so hideously unnatural as a slum is wildly unscientific, as Darwin or Wallace would be the first to point out. The process that we witness in a slum is the damaging of all the life therein. This damage varies in degree in various cases. It kills at all ages, and damages at all ages, according to a multitude of varying circumstances.

The slaughter and the damage are naturally greatest among the most immature and exposed, which are the infants. The urban infants of modern so-called civilised communities are exposed to a combination of artificial conditions of dirt, foul air, improper feeding, alcohol, bacterial infection, darkness, and so forth, which have no parallel anywhere in the living world; and the doings and the results of which are so immeasurably different from anything in Nature that to describe the process as natural selection is simply to raise a dust, and then complain we cannot see.

An Official Report that Shows how Weakness in Infancy is Followed by Weakness

But the overwhelming difference between this process and natural selection is not so much that this is hideously unnatural, which is difference enough, as that natural selection does not damage the survivors, while the causes of infant mortality do.

This is really the central fact of the case, and once it is established the discussion is closed; there is no case left for those Herodians who call this slaughter of the innocents beneficent. Only recently has the fact been demonstrated statistically. Of course, the essential evidence is always in the analysis of individual cases. Statistics depend upon data, and those data are the individual cases. But when the data are sound and relevant, statistical analysis by students acquainted with the factors of the problem is invaluable. That analysis has quite recently been undertaken, and the results have been published by the Local Government Board and Dr. Arthur Newsholme, its Principal Medical Officer, to whom all students of eugenics are so deeply indebted.

Dr. Newsholme has shown, by careful and exhaustive inquiry, that all over the country the infant death-rate and the death-rate at subsequent ages go together. If in a given place infants die at a high rate, so do children and young people at all ages up to adolescence. It is very difficult to ascertain the death-rate at still later ages, owing to migrations. But the evidence is final that, at all ages up to maturity, life is unduly destroyed wherever infancy is unduly destroyed, and life is well maintained where infancy is best maintained. It follows, evidently, that if we want grown-up people at all, and still more if we want them as healthy as possible, we must begin by removing the causes of infant mortality.

The Weeding-Out Process by Illness which Makes Far More Weeds than It Destroys

It is clear that if the same cause equally attacks two babies, one naturally weak and the other naturally strong, the weaker will be the more likely to die. If it could be contrived that the stronger was not also injured, though surviving, there would be something to be said, on brutal and pseudo-eugenic lines, for the process. Once it is proved, however, that the weeding-out process makes far more weeds than it destroys, the argument for it is gone. And, further, the argument at best is not eugenic. Natural selection and eugenic selection may have the same effect and end, but they are fundamentally distinct in method. Natural selection is a selective death-rate, killing those less able to survive, but eugenic selection replaces this selective death-rate by a selective birth-rate; and no form of killing or permission of killing can be anything but a negation of the essential characteristic of eugenics.

The Eugenist has every right to say, and must never cease saying, that many children are born who should never have been born, or, rather, whose lives should never have been begun at all. He has every right to say that the feeble-minded, and the alcoholic, and the insane, and those afflicted with gross transmissible infections, must be so guarded and treated in future that they shall not become parents at all.

Our High Infant Death-Rate that is National Infanticide Worse than that of the East

But the instant he approves of the death of any who live, worthy or unworthy, he is not talking eugenics but its opposite, of which the most familiar and accurate name is murder. That, indeed, is the only name for our infant mortality in this country to-day. It is simply national infanticide on a gigantic scale; and in several essential respects it is much worse than the admitted and proclaimed infanticide which we see in China and many other parts of the world,

to-day and in the past. Deliberate infanticide differs fundamentally from our process in that, like natural selection, it either kills or spares. The survivors go unharmed, whereas the national destruction of infants which we practise is the least part of the evils which follow, for we irretrievably damage many for every one we destroy. This simple difference between the two processes is obviously profound in principle, and only too far-reaching in consequence.

Infanticide in the East at Least Prevents the Numerical Excess of Women

We will not leave it by saying that it need no further be insisted upon, for it will need insisting upon for several decades yet, but we must leave it now. For there is a second and little appreciated difference between admitted infanticide as a social custom, and what we practise; and this difference may almost be argued to have more serious and far-reaching consequences even than the difference between the process which kills *or* spares, and that which kills *and* spoils.

Infanticide as a deliberate practice is almost exclusively, if not quite exclusively, female infanticide. It is not our business here, nor have we time, to study this social fact in detail; it will suffice to note that the reason why female infanticide is so widespread a human practice is partly economic, partly associated with religion, and partly dependent upon the causes which lower the social estimation of women. Its significance for us here is, however, not in its causation, but in its consequence. It steadily tends to prevent a numerical excess of women in the community.

Our national infanticide is of quite another kind, as the recital of two well-known facts may prepare us to realise.

Why are There More Women Than Men, Seeing that More Boys are Born than Girls?

There are always more boys than girls born. Every year we find about 103 or 104 boys born to every 100 girls, a fact not peculiar to this or any country or time, though the proportion varies. But if we look at the adult population we find that there are somewhere about one million and a third more women over the age of twenty-one in this country than there are men. Plainly there must be a huge and persistent loss of male life in the interval; and though this is to some extent accounted for by emigration, we find the dominant fact to be that immature males have a much higher death-rate than immature females. For instance, if we examine such a cause of death as infantile diarrhœa, we find that it persistently kills many more male than female babies. The obvious conclusion, according to the arguments of the "better-dead" school, is that the males are the relatively unfit as compared with the females; and with an answer so obviously foolish, but inevitable, their whole theory collapses. But the truth is simply that female organisms are, at all ages, more resistant to injurious influences than male organisms; and whenever a population, at any age, is exposed to a destructible stress, more females than males will survive. It is forgotten that fit and unfit are relative terms. We have only to eliminate oxygen from the atmosphere and we all die, being unfit *for the conditions*, which is all that the word can possibly mean. But such an atmosphere would be no more unnatural than is a slum or the factory labour of mothers, and in neither case could the process be called natural selection, any more than the result is natural selection if the cook adds arsenic to the food.

The High Infant Death-Rate Chiefly Due to Poisoning by Improper Food

Now, this process of infanticide, which destroys so many males, contributes directly to the vast excess of women which produces such disastrous consequences in our social and economic life; and thus we have two large and cogent reasons why our national infanticide is worse than that which is consciously practised in so many places.

The reader, impatient of paradox, may reply that at least Chinese infanticide is morally worse. But such infanticide is not done with any consciousness of wrong-doing; it is very mercifully done. And if a child is spared for even a day or two it is spared altogether, natural feeling proving stronger than the dictates of custom, and religion, and penury. Our infanticide is anything but merciful, as everyone knows who has lived among these dying babies; and it may well be argued that ours is the moral guilt for permitting a slaughter which we know to be preventable, and which is condemned by the moral code in which we profess to believe.

A host of causes conspire together against infant life, as against the immature life of all living species. But the tremendous destruction of the immature in the forest or in the sea is far more due to starvation than to any other cause; the seed falls on "stony ground," and dies. Infant mortality is practically never due to sheer lack of nourishment, except when that is disguised in the form of improper nourishment; and

this should be catalogued more properly as poisoning than as starvation pure and simple. If we include bacteria as poisons, they being the living laboratories wherein poisons are made, we find that an overwhelming proportion of all infant deaths are due to poisoning. The babies drink poison and eat poison, living poison and dead poison, and when they have been sufficiently poisoned they die. This is not the hand of Providence, nor is it natural selection; it is just poisoning.

The Babies that are Fed and Live, and the Babies that are Poisoned and Die

Of course, babies die in some numbers from such causes as genuine accident, from fire, from congenital narrowness of the digestive canal, from overlying by drunken mothers, or even from the attacks of rats. But if all these and other such causes be added together, they contribute an entirely inconsiderable proportion of all the deaths —probably not so much as 1 per cent. all told.

We justified the statistical convenience of studying separately children under one year old by saying that this period corresponds sufficiently to the great fact of nurture called suckling, breast-feeding, or lactation. And now we are in a position to realise the importance of that fact. Allowing for many exceptions, due to such causes as those above cited, and to alcoholic poisoning, lead poisoning, and some other diseases of the nursing mother, we may, lay down the one central, all-important fact of this entire question, which is that the breast-fed babies are fed and live, and the otherwise "fed" babies are poisoned and die. The great modern pioneer Budin did not make the mistake of too many of his followers. He established milk-depots with much success; and these depots and *crêches* have spread everywhere. But Budin always regarded these as the last resorts.

The Perfect Food for which there is No Perfect Substitute, and Never Can Be

The first resort is the nursing mother; and the Infant Consultations for nursing mothers, which he began in Paris just twenty years ago, and of which our Schools for Mothers are an improved form, have been worth far more than all the milk-depots and *crèches* in the world, because they recognise the importance of the nursing mother, and her incomparable superiority to all substitutes. Large numbers of figures are available on this point. They show that, in various groups of observations, the mortality among hand-fed infants is from three or four to as much as fifteen or twenty times as high as among breast-fed infants.

Undoubtedly the work of Rotch, of Boston, has taught us much in the way of the artificial feeding of infancy. He has shown us how to separate the various constituents of cows' milk, and put them together in due proportion, not only for babies in general, but for babies of various ages, and of various digestive capacity. The methods of Rotch, as practised in this country, now at the Infants' Hospital in London and elsewhere, form the nearest approach to maternal feeding that science can devise; and so perfect are the chemical processes involved that we may probably declare them to be as good as science can ever make them. But they involve a most serious and impracticable expense, in the feeding and care of selected cows, and the protection, carriage, analysis, and subsequent recomposition of the milk. And, at the end of all this, the milk is cows' milk; however "humanised," it is still bovine, not human. There is thus no perfect substitute for human milk, and never can be.

The Protective Power that a Mother Can Give to Her Child

The advantages of breast-feeding to a baby are so many that only a complete study of the physiology of milk could adequately reveal them. Human milk, assuming the nurse to be healthy, is always of the exactly right temperature; it is completely free from microbes, and yet has not been modified or damaged by either boiling, pasteurisation, or the addition of antiseptics.

The milk contains exactly the right proportions of all the constituents necessary for healthy development, and contains nothing else; the special sugar which it contains is highly resistant to alcoholic fermentation, and cannot be replaced, in any artificial diet, by anything but itself—by milk sugar derived from the milk of the cow or some other mammal.

More than this, it appears to be very probable that human milk, and only human milk, contains substances, derived from the mother's blood, which protect the child from various forms of disease. It appears that babies are thus kept immune from the attacks of certain microbes, so long as they are breast-fed, because the milk transfers to them the protective substances which have been formed in the nurse's body when it was attacked by the microbes

in question. It is obvious that if a nurse recovers from, say, diphtheria she will have diphtheria antitoxin in her blood, and this may pass into the milk and so into the body of a suckling, just as certainly as if it had been injected by a doctor.

If we survey the whole history of evolution from the dawn of the mammalia, not forgetting the unparalleled duration of the period of natural lactation among ourselves, who are the highest of the mammalia, and if to this biological evidence we add the positive experience of comparative practice in our own day, as the foregoing paragraphs indicate it, we shall see that the next great business of civilisation, if it is to practise even that *minimum* only of eugenics, without which it cannot possibly persist, is, first, to take care of expectant motherhood, and then to restore that vital association of mother and nursling which modern economics, aided by not a few blind guides of modern womanhood, has so frequently broken. If we are to save infancy, and make the most of what birthrate we have, we must save motherhood, mothers being the natural saviours of babies.

The Great Plan of Health that Nature has Steadily Adhered To

This is Nature's plan, steadily adhered to ever since she invented the Mammalian Order. We have tried, and many of us are still trying, to find substitutes for mothers, and to rear babies by other means. The milk-depot, the *crèche*, the incubator, the fractional analysis of cows' milk, all have their uses and their place; but if any generalisation whatever emerges from the experience of the last twenty years, and especially of the last decade, it is that, the greater and more skilful our efforts to do without the mothers, the more clearly do we learn that we cannot. There is nothing for it but to accept, for this second stage of human nurture, the same principle which was so clearly seen when we were studying its first stage: if the expectant mother is to be the first charge upon the national resources of forethought and material provision, the nursing mother is certainly to be the second.

In this country a great object-lesson was afforded by the magnificent work of Alderman Benjamin Broadbent, who, as Mayor of Huddersfield, encouraged, guided, and rewarded mothers to do their duty to their children. Very few citizens of this Empire have better deserved the title of patriot, and whatever other titles may be worth adding thereto. His work and initiative led to the holding of two national conferences on the subject, the fruit of the first of which was the Notification of Births Act, which came into force in 1908, and under which births require to be notified within thirty-six hours, so that knowledge and help may come to the mother when they are urgently needed.

The National Need for a New Ministry of Public Health

This splendid Act is at present adoptive, but should be compulsory. The demand is here made that the Act be made compulsory everywhere, and be worked in association with the system of maternity benefits under the National Insurance Bill. If we had a Ministry of Eugenics, or even what we shall sooner have, a Ministry of Health, in this country, it would not be possible for maternity benefits to be discussed, in Parliament and outside it, over a period of many months without anyone remembering that the Notification of Births Act already exists, and should obviously be co-ordinated with the new scheme. Somewhat later, as we shall consider in due course, the future mothers of the nation will be taught and trained in vital matters, vital for mothers and therefore for babies and empires, even though they may have to sacrifice therefor some scintilla of accuracy in regard to the imports of Rio de Janeiro, or the parentage and sequence of Henry the Eighth's wives.

The students of the religions of mankind tell us that in the East and in the West, in the remotest ages of Indian or Egyptian culture, as in many manifestations of more recent religions, they find what they can only call Mother-and-Child Worship.

The Everlasting Choice Between the Calf of Gold and the Child of Flesh and Blood

There are few more significant facts in the record of mankind. The ideals and the creed of eugenics, the newest and the oldest ingredient of religion, demand a living practice of mother-and-child worship in our own day. If these religions, ancient and modern, mean anything, they mean that all motherhood has in it something sacred, and that every baby has in it something not of the human only, but of the Divine as well. Everywhere in the coming world we shall find eugenics and hygiene, philanthropy and patriotism, restoring upon deeper foundations than ever the altars of this worship. And ever the choice remains, so long as man is mortal, between the calf of gold and the child of flesh and blood.

GALILEO DISCOVERING NEW WORLDS

In the year 1609 Galileo made his first telescope at Padua, where he was professor of mathematics. He rapidly improved his instrument, and his discoveries in the year 1610 revolutionised all existing knowledge in astronomy. The discoveries of the satellites of Jupiter, the phases of Venus, the composition of the Milky Way, and the spots on the sun followed each other in quick succession.

OUR LONELY SOLAR SYSTEM

The Man who First Inferred that the Earth Moves Round the Sun, and the Man who First Saw that It is so

WILL THE PLANETS GO BACK TO THE SUN?

Many and great universal questions have had to be dealt with before we could really be prepared to take any part of the Universe by itself and consider it in detail. At the very least, we must by now have adjusted our thoughts to the scale of the Universe, and shall see things in their proportions. We are definitely in the third stage or theory of the Universe, so far as sun and earth and stars are concerned. The first imagined the earth to be the centre of all things, and strove to explain the movements of the heavenly bodies in accordance with that idea. This we call the geocentric theory, and it was the basis of a system of astronomy known as the Ptolemaic astronomy, after its best representative. This followed the overthrow of Greek science, and was a poor and clumsy attempt to make a system on a basis which the great Greeks had long before seen to be false and had abandoned.

The step from the geocentric astronomy of Ptolemy to the heliocentric astronomy of Copernicus was the greatest in the history of this most ancient and stupendous of the sciences. We cannot decently begin our account of the solar system without looking at the essential work of the monk Koppernik, or Copernicus, to whom hitherto we have only just alluded; and thereafter we shall remind ourselves that, though the Copernican astronomy, which placed the sun and not the earth in the centre of our system, is true, the heliocentric theory of the universe cannot be maintained, and we require to appreciate the third stage of thought, in which neither the earth nor the sun is at the centre of things, and our utmost efforts fail to reveal any centre of things at all, if such there be.

Copernicus was born in Poland in 1473, and died seventy years later. After studying astronomy and medicine, and becoming a member of the Church, which occupied much of his time, Copernicus began to write his great book on "The Revolutions of the Orbs." This work, one of the supreme classics of astronomy, appeared in 1530, so that we are now nearing the end of the fourth century of the Copernican astronomy. For the first time since the Greeks, two thousand years before, it asserted that the sun and not the earth is the centre of what we now call the solar system, and that the earth and the other planets revolve round it. The argument also asserted that the earth rotates upon its own axis. These are the essential contributions to knowledge made by Copernicus.

He had many difficulties to contend with, which we can only realise if we remember how little was then known. Not until a generation later was an infant to be born in Pisa who should invent the telescope, and not until twice as long a period had passed was Galileo's "old discoverer" to reveal the moons of Jupiter. The enormous importance of this discovery can be seen if we remember that the earth undoubtedly has a moon which revolves round it. At least as regards the moon, the earth is "geocentric." But Copernicus asserted that the earth and Jupiter alike go round the sun; and it would have been a very great argument to be able to point to moons round Jupiter, showing the parallel between one asserted planet and another. Still more powerful was the further argument of Copernicus, which Galileo provided by his discovery of these moons, two generations after the masterpiece of Copernicus was written. For he found four moons, evidently revolving round a central orb, sometimes eclipsed behind it, evidently controlled by it. Here, so to say, was a small model of the solar system as Copernicus asserted it to be. Why should not the sun do with the planets what Jupiter does with his moons? So

important was this discovery of Galileo as confirmation of Copernicus that we cannot refrain from quoting the comment of a great astronomer, the late Professor Simon Newcomb, upon it: "As in the case of the spots on the sun, Galileo's announcement of this discovery was received with incredulity by those philosophers of the day who believed that everything in Nature was described in the writings of Aristotle. One eminent astronomer, Clavius, said that to see the satellites one must have a telescope which would produce them; but he changed his mind as soon as he saw them himself. Another philosopher, more prudent, refused to put his eye to the telescope lest he should see them and be convinced. He died shortly afterwards. 'I hope,' said the caustic Galileo, 'that he saw them while on his way to heaven.'"

Posterity Honours Its Benefactors for What They Did Well, and Forgives Their Mistakes

Copernicus declared that the planets, including the earth, move round the sun in circular orbits. Their orbits are, indeed, not far from circular, but the difference was enough to provide Copernicus with very serious difficulties, which he did his best to surmount, arguing that the planets are checked at times in their flight, so as to account for their appearance where, on the theory of circular orbits, they were not expected to be. We already know that the difficulty arose from the naïve assumption, as it now appears to us, that the orbits of the planets must be circular, the circle being the only perfect figure. But, indeed, it would have been more than one man's work to do all that Copernicus did, and also to undertake the long and complicated calculations which were Kepler's life-work, and enabled him to show that the orbits of the planets are ellipses. Though much that Copernicus taught was wrong, he did his share of adding to the world's knowledge.

The Amazing Isolation of Our Earth and Its Solar Comrades in Lonely Space

A strange and notable fact is that the revolutionary views—as they may be doubly called—of this son of the Church gave no offence to its prelates. On the contrary, it was Luther who objected to them. Copernicus himself suffered nothing. It was reserved for Bruno and Galileo to pay the price for asserting that the earth moves—that the apparently solid and stable centre of all things is flying under our feet in homage to another body, and in company with many other such satellites of his.

Plainly the Copernican astronomy teaches us to look upon the sun and his family as a system, in some measure apart, which we call the solar system, from the Latin name of Sol, the sun. And here we make a discovery that is better made now, when we are convinced that the Universe is a universe, and have clear evidence of the working of such laws as those of motion and gravitation, by which all the heavenly bodies are bound together. This discovery is that the solar system is amazingly isolated in space.

There is no star, nor star-cluster, nor constellation near enough to have any influence upon the solar system that can be measured. It is like an island group in an immense ocean; we are almost tempted to say, in the centre of an immense ocean, and the evidence for and against that view will indeed require to be considered. The sun is certainly one of the millions of stars, but it is extraordinarily remote from the multitudes of stars, and even from its nearest stellar neighbour. When the theory of Copernicus was suggested, and Kepler had advanced it by his laws of planetary motion, and Galileo's telescope had supported it also, in the manner we have seen, astronomers protested that, if the earth really revolves round the sun, at a distance of many millions of miles, the position of the stars should seem different at different times of the year—the constellations should be of a different shape when viewed from opposite sides of so great an orbit.

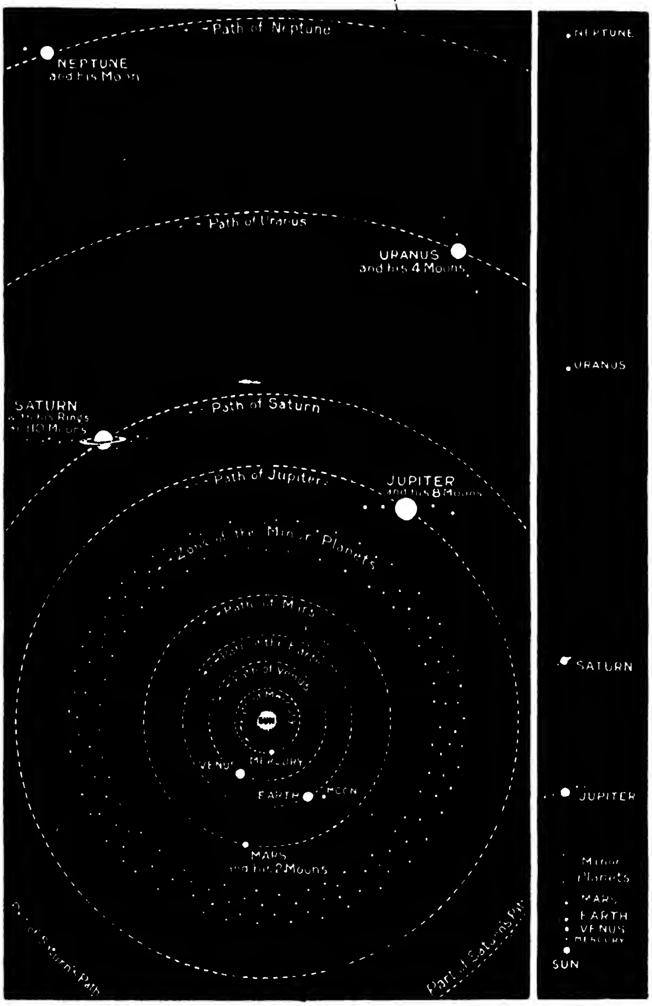
The Orbit of the Earth Only a Point in the Immeasurability of the Cosmos

The pioneers all declared that the stars did not appear to alter their relation to each other, not because the earth did not indeed move through a great distance, but because the distance of the stars from the earth is so huge that the whole orbit of the earth is a mere point in comparison. They were quite right. Even the nearest star is more than twenty billions—that is, millions of millions—of miles away, so that the light from it takes more than four years to reach us, travelling more than 186,000 miles in every second of that time. The next nearest star is not far short of twice this distance away from us.

These are questions which must be considered in their place when we come to study the stars, the dimensions of the stellar universe, and the distances of the stars from each other. But the present point is essential. If such be the distances of the stars from the earth—that is to say, from the solar system as a whole—the conclusion is evident. Let us grant that Neptune, the

remotest of the sun's family of planets, is nearly 2800 millions of miles distant from him. Even so, compared with billions, it is evident that the solar system, as well as the sun himself, is a group apart in space. Gravitation, radiation-pressure, and possibly other influences are at work. The solar system *is* part of the Cosmos. Yet, plainly, just as we call man a microcosm, or little cosmos, in the macrocosm, or great cosmos, so the solar system is a microcosm in the great Cosmos. It is so amazingly removed from the influences outside it that their action upon it cannot be traced, and we may study, for instance, the mutual influence of sun and planets without taking any account whatever of the gravitation of the stars, though most of them may be far larger than the sun itself; or of nebulæ in which the whole solar system might be plunged and lost for ever.

This isolation may not have always been so, nor need it always be so. In due course we must ask the whence and whither of the solar system, for we shall discover that it is in motion as a whole. Yet that motion is so slow, compared with the unthinkable distances that separate us from the stars, that it is meanwhile negligible. So far as we can judge the motions of the sun and the other stars, the solar system must have been isolated for unthinkable ages in the past, and must continue to be so for unthinkable ages to come. So much we must admit; but there is a possibility which most astronomical writers have forgotten, because the dark stars are scarcely remembered in our speculations yet. It is that dark stars may be nearer to us than the nearest bright ones we know, and that these dark stars may have a motion, or one of them may have a motion, which is bringing it towards the sun. In the course of time such a star would affect the movements of the solar system, and its existence and approach could be detected by astronomers. That, also, is a matter for future consideration; but, meanwhile, when we admit the isolation of the solar system, we are bound to add that we are assuming the non-existence of dark stars in our nearer neighbourhood. However, there are none such near enough to affect the motions within the solar system now.



PLANETS AND THEIR MOONS THAT REVOLVE ROUND THE SUN
The diagram shows the order in succession of the planets from the sun outwards, but it cannot represent comparative distances, nor the shape of the orbits. The scale on the right shows the relative distances of the planets from the sun.

The modern calculations of astronomy thus entirely justify the feeling of poets, and lovers, and philosophers in all ages, that the stars are terribly remote, and utterly without concern for human joy and sorrow. Such reckonings conversely dispose of the idea of the astrologers that, indeed, the stars have immediate influence upon men, as when Romeo, in his last speech, says:

> And shake the yoke of inauspicious stars
> From this world-wearied flesh.

That view is proved absurd by the modern study of the isolation of the sun, and the wisest of the past have always known it. Thus Shakespeare speaks what he himself believes when he says:

Men at some time are masters of their fates;
The fault, dear Brutus, is not in our stars,
But in ourselves, that we are underlings.

The Awful Splendour of the Everlasting Calms of Space Between the Stars

And the philosophical view, now verified, is nowhere better expressed than in the words which Tennyson puts into the mouth of the great philosopher-poet of the past, Lucretius:

The lucid interspace of world and world,
Where never creeps a cloud, or moves a wind,
Nor ever falls the least white star of snow,
Nor ever lowest roll of thunder moans,
Nor sound of human sorrow mounts to mar
Their sacred everlasting calm!

Such is the just view. It is awful, but it is splendid. It needs repeated and various assertion in these days, when a strange recrudescence of mediæval superstition is to be found even in the "educated" classes, and when men and women daily consult astrologers, and have their horoscopes read, and marry or commit suicide on account of what they are told. It is time to have done with such things, and vastly better to accept the truth as science demonstrates it to-day. Psychical and spiritual forces there may and must be, which science cannot reckon with nor deny, but not the influence of those incredibly remote masses of matter—they are no more—which we call the stars.

The solar system, then, is alone in the world, at present; and it hangs together, like a little universe, in virtue of the laws of gravitation and motion. In virtue, also, we must add, of its origin in a single object, from which it has derived the arrangement of motions that makes its balance possible. Thus, to take only one instance, the planets all travel in the same direction. Moving at different rates they may overtake one another, but they never meet and pass one another like trains on opposite lines. The system could not persist in such a case.

The Irony of a Mocker of Perfection Turned By All We Know Into Sober Truth

Thus we have to reckon with not only the laws of gravitation and motion, but also the original disposition of the parts of the solar system, and the common origin of the motion of its parts, before we realise why it holds together as it does. And, so far as the present state of things is concerned, we may almost accept the half-ironical words of Carlyle at the beginning of "Sartor Resartus": "Our Theory of Gravitation is as good as perfect: Lagrange, it is well known, has proved that the Planetary System, on this scheme, will endure for ever; Laplace, still more cunningly, even guesses that it could not have been made on any other scheme." We shall find facts which Lagrange had not reckoned with, nor Laplace either, but the laws of gravitation and of motion are not "as good as perfect," but perfect; and they permit us to study the solar system, provisionally and in the first place, as a stable and permanent object, whatever its origin and destiny.

What, then, does this object consist of? Let us make a list of its items—a census of the universe within a universe, to which our earth belongs. There is, first, the sun. We may call it, for convenience, the centre of the system, if we remember that it is not in the centre of anything, but in one or other focus of the ellipses which the planets describe round it.

An Analysis of All that Makes Up Our Self-Contained and Isolated Solar System

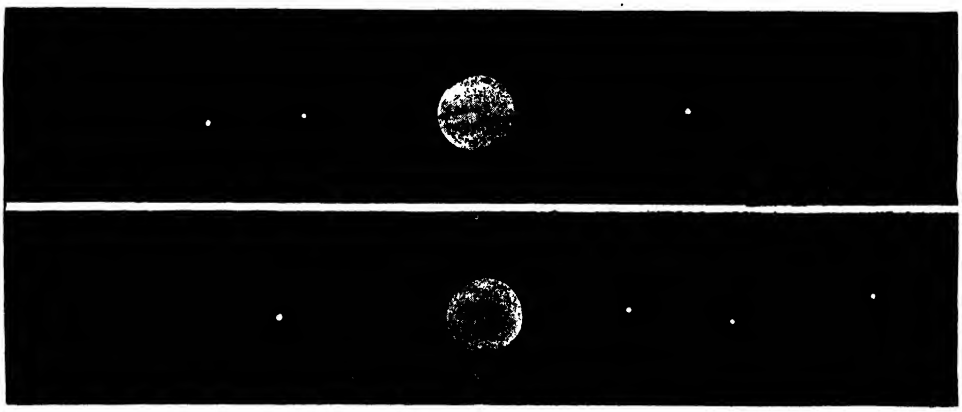
In another sense the sun may be the centre of the solar system, for probably it is the "centre of mass," or "centre of gravity," of the system, and represents to-day the centre of gravity of the nebula from which we presume the solar system to have been formed.

Next there come the major planets, or satellites of the sun. Some of these travel in orbits inside that of the earth, and others travel in orbits outside the earth's. Then there are the minor planets, several hundreds in number, some of which have names, but most of which have only numbers. Many of these minor planets are far smaller than the moon. Nevertheless they are planets, travelling in elliptical orbits round the sun, as the earth or Jupiter does. The moons of those planets that possess them furnish a further group in our list. They are satellites of the sun, for they undoubtedly travel round him, but they are also satellites of the sun's satellites; and their actual course in the sky, unlike the regular, forward, curved path of a planet, is extraordinarily complicated, combining motion round their "primary," as their planet is called, with motion round the sun. Though they may be much larger than many or any of the minor planets, their position in the solar system is clearly secondary.

Sun, planets, major and minor, and their satellites, constitute the more evident parts of the system. But comets have to be included, though so very different in form and size and composition. Here the numbers must necessarily be vague. We can say that there are eight major planets, with not less than twenty-six satellites between them, and not less than seven hundred minor planets or "asteroids." These all definitely belong to the solar system. The same may be said of not less than twenty comets, each of which moves in a known elliptical orbit. They may be a very long time, even three-quarters of a century, in returning to the sun, but they do return, as we know both from actual observation of many, and, in the case of others, by the fact that the elliptical character of their orbits can be proved. But other comets appear to move in paths of another kind. Instead of moving in any closed curve, like an ellipse, which returns upon itself, they seem to move in paths which are open, parabolas or hyperbolas, so that they pass round the sun once, and are never expected to return. Such comets would dash away beyond the outer limit of the solar system, though with steadily decreasing velocity, in consequence of the sun's retarding influence upon their flight away from him; but if their paths were really not elliptical, they could not return, but would move on until they came under the influence of another sun, which they might visit similarly. Of such comets the amazing words might be said, they go from star to star; visiting and twice passing through one star and its system after another. If such were the case we could not reckon them as really members of our solar system.

But, as we shall see later, it appears more probable that the views on this subject, hitherto accepted, are erroneous. Probably the paths of all comets are elliptical. They do return to the sun, and are as truly members of the solar system as the earth is. But they may pass immeasurable distances into space, far beyond the orbit of Neptune, before they begin the return journey, and the mere span of human knowledge and record may be pathetically inadequate for the proof of their return. Thus we cannot say at all how many comets, really members of the solar system, may now be in space, some travelling towards, some travelling away from the sun, but none yet seen by human eye. And certainly, if we were to be strict in our definition, and were asked to state the dimensions of the solar system, we should have to state not merely the diameter of the orbit of Neptune, but a figure wide enough to accommodate the orbit of whatever comet, known or unknown, travels furthest from the sun. If we reject the idea of comets which never return, we may probably also reject that of comets which have approached the solar system from outer space and have then been "annexed" by the sun. It is not probable that this has happened. More likely is it that all the members of the solar system are original members, and none of the sun's family are his merely by adoption.

Meteors or shooting-stars must be included also in our list of the solar system. The numbers here are enormous, and



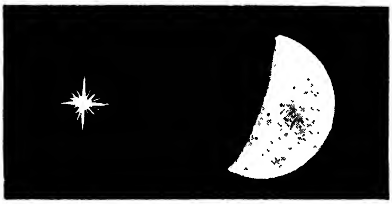
JUPITER AND ITS MOONS AS GALILEO SAW THEM

When Galileo first looked at Jupiter through a telescope on January 7, 1610, he saw that Jupiter was a globe having three moons, two on the left and one on the right; looking again on January 13, he saw four moons, one on the left and three on the right, and this revealed to him the new fact that the moons were revolving round Jupiter. Jupiter's moons can be seen on a clear night through a good field-glass.

cannot be entered, even approximately, in our census. We shall learn later that these bodies have a historical relation to comets, and some of them travel in paths similar to those of comets, or in paths which were formerly followed by comets. As meteors reach our earth they seem to come from all directions of space, quite irregularly. Others, again, appear to come from the direction of certain constellations, such as Leo and Perseus, and are called the Leonids or Perseids accordingly. Since they are often called shooting-stars, this name, and their association, apparently in place and also in their special designations, with real stars, often confuse people. But meteors are not stars, and have nothing to do with stars or constellations. Notwithstanding their apparent irregularity of motion when they reach the earth, they are true satellites of the sun, and just as definitely members of the solar system as the earth is. They have their own orbits, as the earth has, and their passage into our atmosphere is an accident dependent on the fact that the earth's orbit and theirs may sometimes coincide. This will be enough to establish our present point—that meteors are indisputable parts of the solar system, and must be included in any catalogue thereof.

A vast multitude of bodies which must be very like meteorites constitute the famous rings of the planet Saturn. They are not moons—of which Saturn has an unparalleled supply as well—and they are not included under meteors in general. These also, however, are part of the solar system.

Great quantities of matter in finer form must also exist in the spaces between the planets. It is so fine that we might compare it to dust, and "cosmic dust" is the name by which the astronomers know it. This material must presumably travel in orbits round the sun, if it is not to be drawn into the sun by gravitation. The discovery of radiation-pressure complicates the case, however, and may serve to keep cosmic dust away from the sun, even apart from any orbital motion, such as keeps the planets from being drawn inwards. Thus cosmic dust seems trivial, but is not so. For one thing, it may be derived from the mutual clash of meteorites, and may thus be really of cometary origin, as meteorites are. But it is also important because its presence in space, between us and the stars, rather complicates our problem of seeing the stars. If there be much of it, and especially if any cosmic dust exist in the vast spaces between the solar system and the stars, evidently some of the light of the stars will be absorbed as it passes through space. Now it makes a profound difference to astronomical calculations, and above all to the question of the limits—if such there be—of the stellar universe, whether or not there is absorption of light in its passage through space. If such there be, then the gradual thinning of the stars, as we pass outwards through the Universe, is only apparent; if there be no such absorption, the thinning of the stars and their ultimate absence from space beyond a certain distance, or in certain directions, is real, and means that, in such cases, we have really got beyond the universe of stars to which our sun belongs. These are questions now in controversy, and they must be duly considered when we have to study the starry universe; meanwhile we must note that "cosmic dust" does exist, and that what we know at first hand—for some of it reaches the earth—must certainly be included as part of the solar system.



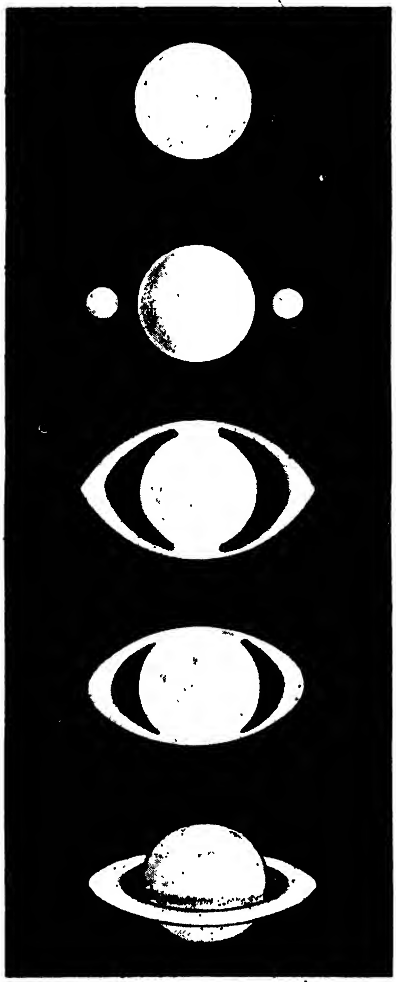
VENUS REVEALED AS A PLANET
Before September, 1610, all men believed Venus to be an ordinary star, but at that time Galileo's telescope showed it as a half-moon, proving it to be a sphere lighted by our sun

In this catalogue of the solar system, which includes the results of the present century's work, and is the most comprehensive yet published, we must include countless billions of particles smaller than those of cosmic dust, smaller even than the very atoms of matter. For we have lately learnt that the sun, like other radiant bodies, is constantly shooting forth from its surface a stream of electrons, electrical particles, vastly smaller than atoms, which fly outwards through the solar system at vast speeds, and many of which strike the earth's atmosphere. Their production by the sun varies in intensity at different times, but they are continuously produced, and are certainly part of the solar system, though we cannot yet trace the destiny of those—doubtless immeasurably the greater number—which do not strike any planet in the course of their outward flight. Probably they ultimately obey the law of gravitation and return to the sun; but it is imaginable that they may travel so fast as to pass beyond the range of his influence, and so be

lost to the solar system for ever. But until they do so—if they do so—they are parts of it.

All the members of our catalogue up to this point undoubtedly exist. But we must also mention two supposed members of the solar system, one of which, no longer believed in, has actually received a name. Remembering how difficult it must be to notice a small planet very near the overwhelming brilliance of the sun, we may surmise the existence of a planet whose orbit is inside that of Mercury, the known planet nearest the sun. The name of Vulcan has been given to the supposed intra-Mercurial planet. Observers have supposed that they have seen it in transit, as a dark object, across the face of the sun, as Venus or Mercury may be seen. Others have supposed that they have seen it during a total eclipse of the sun, when a small planet near the sun would have a chance to show itself. But the general belief among astronomers now is that the modern Vulcan is but a dream of the imagination.

Much more recently, and indeed at the present time, astronomers are asking whether there may not be a planet outside Neptune, which is the known planet furthest from the sun. Just as peculiarities in the movements of Uranus, its inner neighbour, led to the discovery of Neptune, so peculiarities in the movements of Neptune might lead to the discovery of an outer neighbour. But such inquiries must demand much time Neptune takes nearly 165 years to complete one revolution round the sun That is the Neptunian year. But the eye of man only recognised the planet, for the first time, sixty-five years ago, so that Neptune has not yet nearly completed half a journey round the sun since its discovery. The discovery of a new planet might extend the bounds of the sun's kingdom by as mighty an area as did that of Neptune itself. Failing Vulcan, and this unnamed and hypothetical planet beyond Neptune, our catalogue of the solar system is now complete, if we allow for the not unlikely discovery of more moons, such as the present century has already added to Jupiter and Saturn, and of more asteroids or minor planets and comets.



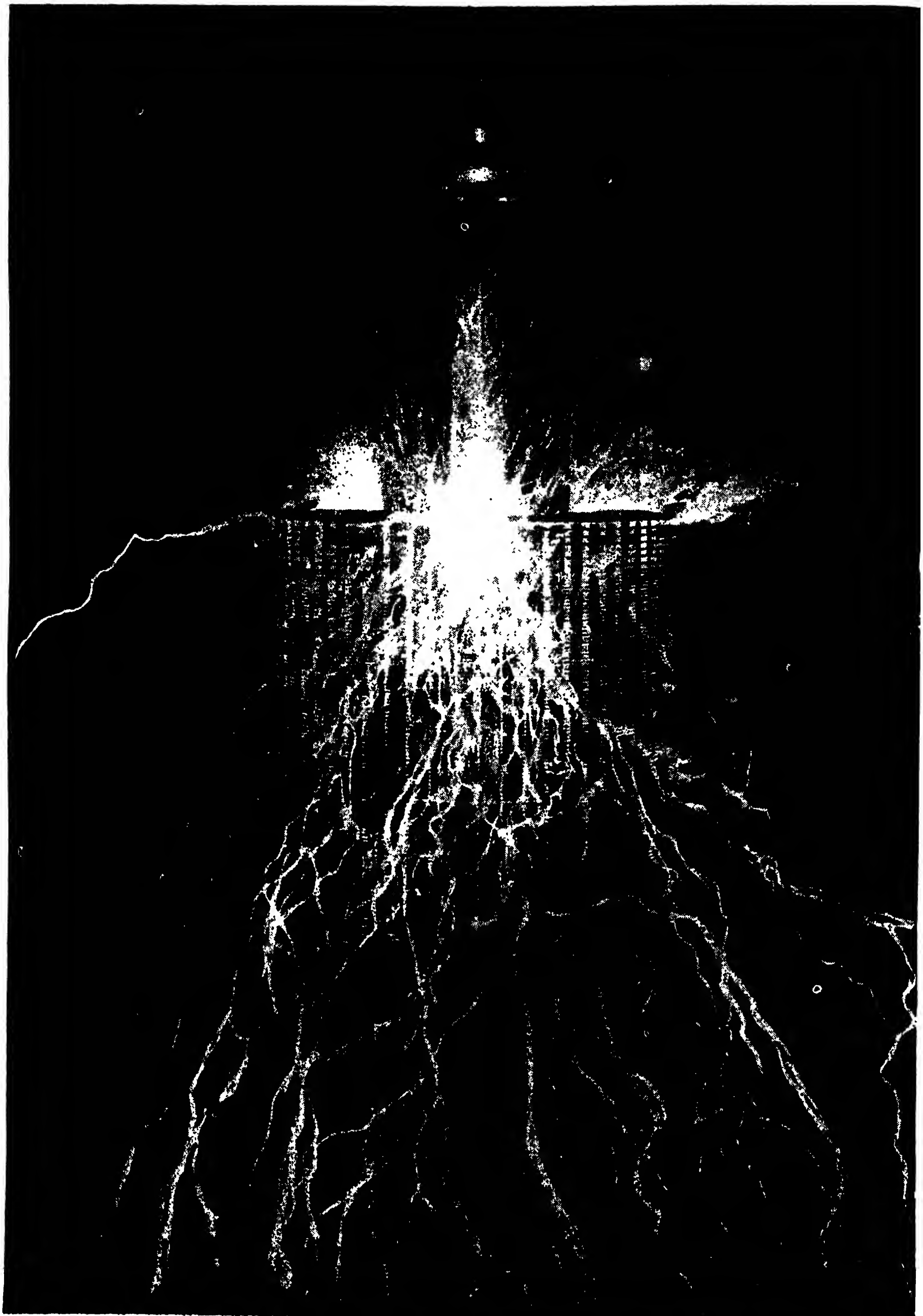
THE DISCOVERY OF SATURN'S RINGS

The four upper pictures show how Saturn appeared through Galileo's imperfect telescope, causing much speculation and mystery. The bottom picture shows the clearer view obtained in 1656 through the more perfect telescope of Huygens.

The list of the planets, in order outwards from the sun, will thus run, Mercury, Venus, Earth, Mars, minor planets, Jupiter, Saturn, Uranus, Neptune. The task now before us will be to ascertain how this system of bodies came into being, or even how any of its individual members may be supposed to have come into being This is the problem of planetology, or the birth of planets, which foreshadows the more stupendous problem of the birth of suns or stars. Then we must ask ourselves what changes are now occurring, if any are, to produce a different solar system in the future, or to end its history altogether—changes great and steady, not merely the diversion of a comet from its ancient orbit by the gravitational force of Jupiter, or any such local, if remarkable, occurrence. And then we have to ask a wholly distinct but no less important question—the whence and the whither, in universal space, of the solar system.

Meanwhile our problem is not an impossible one, in some degree, for we have an isolated system to study—a little universe which is comparatively small, and so accessible to our telescopes that at least one moon of the remotest of the planets can be detected. Compared with any system round a double star, ours is thus intelligible, and evidently single and orderly.

THE BORDERLAND OF FORCE AND MATTER



This striking photograph of an electric discharge takes us into a region of investigation where a new epoch of science is being inaugurated. Thus, when an electric discharge is sent through a vacuum glass tube, it produces in the tube an exquisite glow, caused by what Sir William Crookes has called "Radiant Matter," a fourth state of matter beyond the solid, liquid, and gaseous states.

WHAT THINGS ARE MADE OF

The Revolution of Radio-Activity that Finds Everything Compounded of the Same Ultimate Material

THE SECRET OF THE INFINITELY SMALL

We now come to the most interesting subject of radiant matter; but, before we can understand the full significance of radio-activity, we must look at the manner of its discovery and consider its relationship to kindred phenomena.

In the first place, let us observe for a moment the common forms taken by matter, and the relationship between these forms. As we all know, we meet with matter either in solid, liquid, or gaseous form. But it is not always recognised that these forms have no real importance, and vary with the thermal condition of the substance. We talk of water and mercury as liquids, and of iron and gold as solids, and of oxygen and nitrogen as gases. But the difference is just a difference of the distance between their molecules, and really amounts to little more than the difference between snow lying loosely on the ground and snow squeezed into a snowball, and to no more than the difference between steam and water. In a gas the molecules are so loosely compacted that they can fly about, and go for a certain distance without collisions. In a liquid they are loosely disposed, so that they easily slide over each other. In a solid they are packed together, so that they have not much room to move.

The nitrogen molecules in this room are flying about at a rate of about a quarter of a mile a second; the oxygen molecules go almost as fast; and any molecules of water vapour go considerably faster, and every second each molecule collides millions of times with its neighbours. In like manner the molecules of all gases fly about and collide with each other.

The molecules of liquids are not so mobile, but even the molecules of liquids are in motion. The molecules in a drop of water are as active as a swarm of bees, and between the molecules there is plenty of room. The amount of room can be demonstrated by adding a soluble salt to water. It will be found that the dissolved salt does not increase the bulk of the water, and therefore its molecules must have found accommodation between the molecules of the water.

Even in solids there is a movement of molecules. Thus, in a diamond the molecules are in motion, and we ought "to picture to ourselves any body whatever, such as a block of steel or a rigid fragment of rock, as being composed of isolated elements in motion, but never in contact."

Clifford gives a pretty picture of the different behaviour of the molecules according to their sphere of action.

"The molecules of gases," he says, "do not fly far in any one direction, but any particular molecule, after going over an incredibly short distance—the measure of which has been made (in the case of hydrogen about 1-250,000th of an inch)—meets another not exactly plump, but a little on one side, so that they behave to one another somewhat in the same way as two people do who are dancing Sir Roger de Coverley. They join hands, swing round, and then fly away in different directions.

"In the case of a liquid it is believed that the state of things is quite different. We said that in the gas the molecules are moved in straight lines, and that it is only during a small portion of their movement that they are deflected by the other molecules, but in a liquid we may say that the molecules go about as if they were dancing the grand chain in the lancers. Every molecule after parting company with one finds another, and so is constantly going about in a curved path, and never sent quite clear away from the sphere of action of the surrounding molecules. In the case of a solid quite a different thing takes place. In a solid every molecule has a place, which it

keeps; that is to say, it is not at rest any more than a molecule of a liquid or a gas, but it has a certain mean position which it is always vibrating about and keeping fairly near to, and it is kept from losing that position by the action of the surrounding molecules."

But even in a solid the molecules do not always retain their mean position. Sir Robert Austen laid pieces of lead and gold flatly against each other, and after four years he found appreciable quantities of gold had penetrated one-fifth of an inch into the lead.

What it is that Makes the Difference Between Solids, Liquids, and Gases

The difference between a solid and a liquid and a gas, then, is essentially just a difference of the distance between individual molecules, with consequent difference in freedom of movement. If the molecules are far apart we have a gas; if nearer together, a liquid; if nearer still, a solid; and any substance can be changed from a gas into a liquid, and from a liquid into a solid, simply by bringing its molecules progressively closer together by cold and pressure, and can be reconverted from a solid into a liquid, and from a liquid into a gas, simply by progressively causing a separation of its molecules by heat. It is a mistake to say that one substance is a gas, and another a liquid, and another a solid. All are potentially gas, liquid, and solid, and the condition in which each happens to be is just a matter of heat and pressure.

We see these three states illustrated in water, which, within the limits of ordinary temperatures, changes from gas into liquid, and from liquid into ice. And we see the same versatility in other substances when we subject them to changes of temperature and pressure. Thus when we heat mercury it volatilises as a gas, and when we cool it down to 39 deg. centigrade it becomes a solid. At ordinary temperatures air is a gas, but by pressure and cold its molecules may be gathered together into a liquid or a solid.

An Amazing Scientific Forecast Made by the Great Genius Faraday

Matter then is well known and well understood in these three forms, but of recent years scientists have been compelled to take cognisance of a fourth more mysterious form, the form which may be distinguished as radiant matter. This fourth form was foreseen by that great genius Faraday, who nearly a hundred years ago, when he was only twenty-four years of age, made a most amazing forecast.

"As we ascend," he wrote, "from the solid to the fluid and gaseous state, physical properties diminish in number and variety, each state losing some of those which belonged to the preceding state. When solids are converted into fluids all the variations of hardness and softness are necessarily lost. Crystalline and other shapes are destroyed. Opacity and colour frequently give way to a colourless transparency, and a general mobility of particles is conferred.

"Passing onward to the gaseous state, still more of the evident characters of bodies are annihilated. The immense differences in their weight almost disappear; the remains of difference in colour that were left are lost. Transparency becomes universal, and they are all elastic. They now form but one set of substances; and the varieties of density, hardness, opacity, colour, elasticity, and form, which render the number of solids and fluids almost infinite, are now supplied by a few slight variations in weight, and some unimportant shades of colour. . . . If we conceive a change as far beyond vaporisation as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes arise, we shall, perhaps, if we form any conception at all, not fall far short of Radiant Matter; and as in the last conversion many qualities were lost, so here also many more would disappear."

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About fifty years later, in 1865, it was found possible to get new spectra from ordinary elementary bodies by subjecting them to great heat, and similar spectra were obtained from elements in the sun and in certain of the stars. And these new spectra undoubtedly indicated a radical change in the nature of the gaseous elements, and were supposed by some to be produced by broken atoms.

But the actual detection of radiant matter —of matter in a state neither solid, nor liquid, nor gaseous—did not take place till some years later, and came about in a most interesting way.

It may be said that Sir William Crookes was the first man to bring radiant matter within reach of laboratory methods, and to realise its deeper significance. He was studying the effects of electrical discharges sent through a glass tube almost completely emptied of air, when he met and recognised this fourth form of matter. A German

scientist, J. W. Hittorf, had noticed that electric discharges through such a tube produced an exquisite glow in the tube, and Sir William Crookes was really investigating this glow. By ingenious methods he succeeded in making a much more perfect vacuum than had ever been made before, and succeeded in showing that the glow in the glass was probably caused by its bombardment by infinitesimally small particles which were discharged from the negative electrode. He found that these particles could be attracted and repelled by magnets, and that they therefore must carry electrical charges, and he found out other interesting facts about their behaviour, but he did more than this, for he saw their deeper meaning; and with the penetration of genius he came to the conclusion that the particles were particles of matter in the fourth form foreseen by Faraday so long before—that they were the *prima materia* of the universe. Here are Sir William Crookes' very words, which deserve to be recorded as the words of a great seer.

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"In these highly exhausted vessels, the molecules of the gaseous residue are able to dart across the tube with comparatively few collisions, and, radiating from the pole with enormous velocity, they assume properties so novel and so characteristic as to entirely justify the application of the term borrowed from Faraday, that of *Radiant Matter*. . . . In studying this fourth state of matter, we seem at length to have within our grasp and obedient to our control the little indivisible particles which, with good warrant, are supposed to constitute the physical basis of the universe. We have seen that in some of its properties Radiant Matter is as material as this table, whilst in other properties it almost assumes the character of Radiant Energy. We have actually touched the borderland where matter and force seem to merge into one another, the shadowy realm between the known and the unknown, which for me has always had peculiar temptations."

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Before long many of the acutest minds in the world were studying the characters of these particles, and many wonderful things about them were found out in many wonderful ways; and in 1897 Professor J. J. Thomson succeeded in proving that the particles have a mass only one thousandth that of a hydrogen atom, that they move wth tremendous rapidity, and that they carry charges of negative electricity equal to the charges carried by atoms of hydrogen. The proved proposition that the particles have a mass only one thousandth that of hydrogen was plainly most revolutionary. Up to this time the smallest particles of matter known to science were atoms, and the smallest known atom was the hydrogen atom, and, lo, here was a particle with only one thousandth the mass of a hydrogen atom. And it comported itself in most amazing ways, neither like a molecule in a gas, nor like a molecule in a liquid, nor like a molecule in a solid.

The Unthinkable Speed of the Infinitely Small Particles of Radiant Matter

The fastest gaseous molecule we know is the hydrogen molecule in gaseous condition, and it flies only about a mile a second, or 60 miles a minute, or 3600 miles an hour. A cannon-ball can go about 2000 miles an hour. The earth rushes round the sun at the rate of 19 miles a second, or 1140 miles a minute, or 68,400 miles an hour. Arcturus goes faster still, no less than 375 miles a second, or 22,500 miles a minute, or 1,350,000 miles an hour.

These are all great speeds, yet all these racers are caterpillars and tortoises compared with the primary particles, for these flash along at the rate of perhaps 10,000 miles a second. They can do, therefore, about three times as many miles in a second as the nimble hydrogen molecules can do in an hour. Of all rapid things we know, only light, heat, and electric waves move faster.

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Though the electrons are so small their momentum is comparatively great, and when they strike an easily movable object they tend to move it. In some way also they are able to move and rearrange the molecules in various substances. Thus, if the electrons impinge on rock salt, the rock salt becomes a beautiful violet colour, and certain gems are changed in colour if

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Though the electrons are so small their momentum is comparatively great, and when they strike an easily movable object they tend to move it. In some way also they are able to move and rearrange the molecules in various substances. Thus, if the electrons impinge on rock salt, the rock salt becomes a beautiful violet colour, and certain gems are changed in colour if

battered by the electrons. One of the most wonderful properties of the electrons, though perhaps it is not so very wonderful considering their minute size and speed, is their power of passing through solid substances. The power of penetration of the electrons depends on the density of the substance; the less dense the substance, the more penetrable is it to the electrons. Taking advantage of this fact, it is possible to make a little window of aluminium (which is a metal of small density) in the vacuum bulb by means of which the electrons can escape to the outer air.

How These Tiny and Nimble Electrons Make the Air a Conductor of Electricity.

We have stated that the electrons carry an electric charge equal to the charge carried by an atom of hydrogen. Now, this is a very extraordinary thing that particles, having only one thousandth the mass of hydrogen, should yet be able to carry an equal electric charge; and, as we shall see later, it seems quite possible that the electron is all electricity together—hence the name electron, that has been given to it. A very characteristic property of the electrons is their power of rendering gases, such as, for instance, the air, conductors of electricity. Thus, if we have a charged body insulated from the earth, it will retain its charge of electricity for a long time, but if a few electrons are shot through the air around it, the air becomes a conductor of electricity, and the electric charge quickly leaks away.

Since they carry electric charges, the electrons can be deflected from their course by magnets; and the magnetic force required to deflect them to a definite degree helps us to find out their mass and velocity relative to their electric charge.

The Electron's Property of Causing the Vapour in the Air to Gather Into Drops.

Finally, the electrons have a very interesting property, the property of condensing vapour in the form of drops. We shall see later that rain-drops and mist-drops always gather round specks of dust in the air, which serve as points of condensation. The electrons can take the place of dust in this respect; and if a stream of electrons be passed through humid air a mist of fine drops at once forms, and the drops gradually descend to the ground. This property is of particular interest, for by means of it the number of electrons can be calculated, and thus the electrical discharge of each can be ascertained. The calculation is made in the following ingenious way. From the rate of the descent of the drops, their size can be estimated; and so, if we measure the total amount of water condensed, we can find out the number of individual drops of that size required for its making, but the number of the drops gives the number of electrons that condense them, and thus the number of electrons is ascertained.

Let us now briefly capitulate the properties of the electrons we have mentioned.

They have one-thousandth the mass of a hydrogen atom.

They carry the same electric charge as a hydrogen atom.

They fly at the rate of about nineteen thousand miles per second.

They are deflected from their course by a magnet.

They render gases conductors of electricity.

They heat bodies they hit.

They cause molecular change in some bodies they hit.

They cause phosphorescence in some bodies they hit.

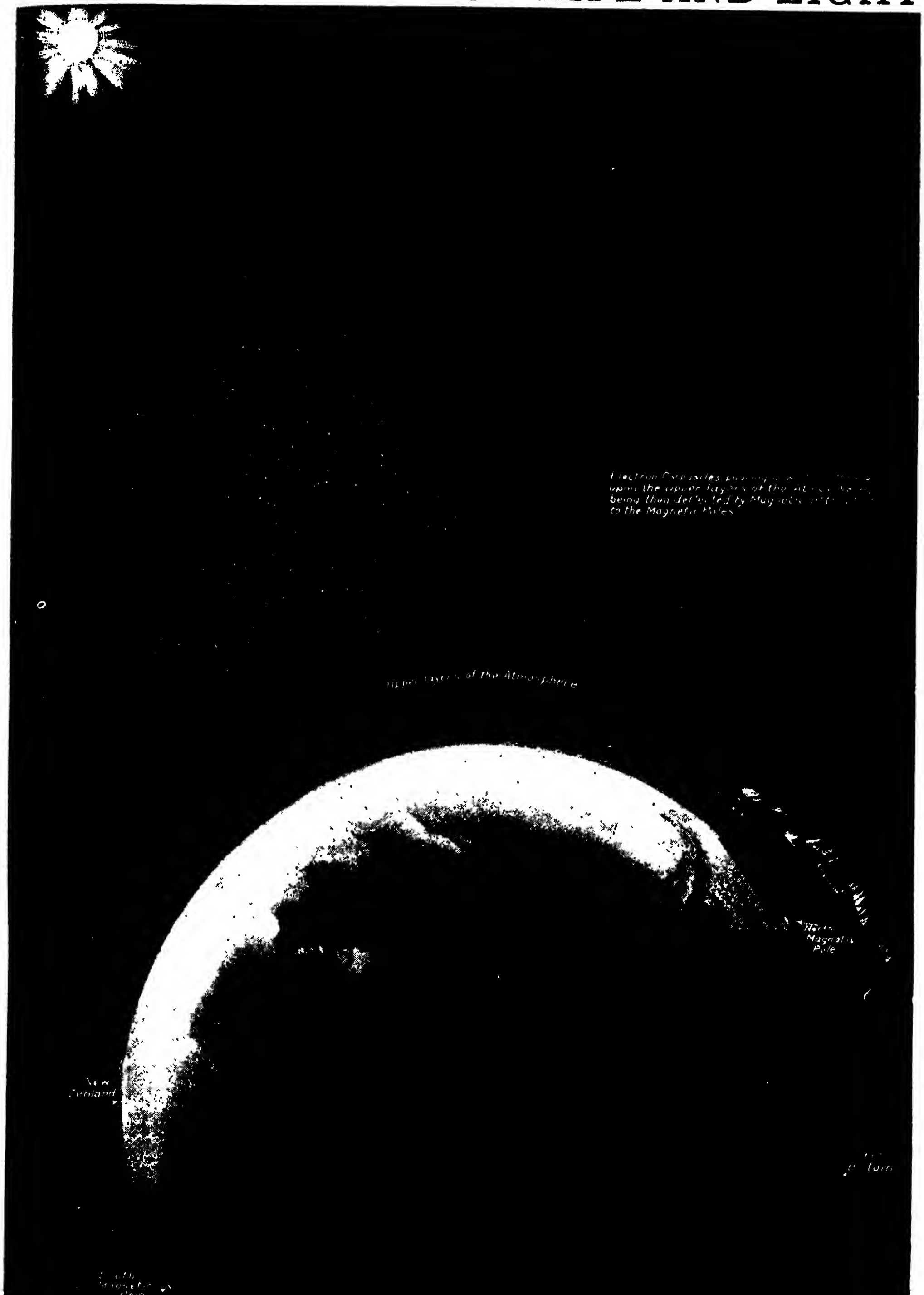
They serve as centres of condensation for moisture in the air.

A Discovery that has Shaken the Foundations of Chemistry Like an Earthquake

These, then, are the most important characters of the electrons, and certainly neither the molecules of gases nor of liquids nor of solids have similar characters.

But let us now look at the origin of these wonderful particles. Where exactly do they come from, and why? They radiate from the negative electrode in the vacuum tube, and they are certainly derived from it. But they have a mass equal only to a thousandth of the mass of hydrogen atoms, therefore they are certainly neither whole molecules nor atoms, and must be bits of atoms. There, then, as we said before, is a most revolutionary fact; it shook the foundations of chemistry like an earthquake. For the atom was considered the most indivisible and indestructible thing in the universe. Newton held that the atoms, "being solids, are incomparably harder than any porous bodies compounded of them, even so very hard as never to wear or break in pieces, no ordinary power being able to divide what God Himself made in the first creation." Dalston maintained that "we might as well attempt to introduce a new element into the solar sytem as to create or destroy a particle of hydrogen." Clerk-Maxwell eloquently affirmed: "Natural causes, as we know, are at work which tend to modify, if they do not at length destroy, all the arrangements and dimensions of the earth and the whole solar system. But though, in the course of ages, catastrophes

SUN-FED STREAMS OF LIFE AND LIGHT



This picture-diagram illustrates a remarkable theory that there exists inconceivable energy ceaselessly pouring from the sun in the form of electrons, infinite numbers of which, on reaching the upper layers of the earth's atmosphere, are deflected towards the two magnetic poles, where they are believed to produce the phosphorescent glow known as the Auroræ, or Northern and Southern Lights.

have occurred, and may yet occur, in the heavens, though ancient systems may be dissolved and new systems evolved out of their ruins, the molecules out of which these systems are built—the foundation-stones of the material universe—remain unbroken and unworn."

The Supposed Indivisible Shown to be Only a Thing of Tiny Fragments

A few wise men, it is true, were not so dogmatic, and, reasoning on philosophic principles, were of the opinion that the different elements were formed by combinations of still smaller ultimate homogenous units; but the general opinion of scientists was that atoms were quite indivisible and indestructible. No wonder. All chemical and natural changes seem to show it. An atom of hydrogen belched from Vesuvius might drift in a cloud to the Gulf of Mexico, might fall in a thunder-shower on a sugar plantation in Jamaica, might become part of the sugar in a cup of tea, and might pass thence from the liver of a man into his muscles, and from his muscles into the muscles of a worm, and from a worm into the crop of an early bird, and undergo a million other vicissitudes, and yet, so far as science could discover, one was bound to believe that the hydrogen atom would remain exactly the same in size, weight, capacity for speed, and all other characters. No form of violence, no chapters of changes, seemed able to disrupt these foundation-stones of the universe.

And yet here were fragments of the foundation-stones flying about inside a vacuum tabe and making the glass blue and green. There was no doubt about it; there they were flying about nineteen thousand miles a second, condensing moisture, rendering substances phosphorescent, and doing many other quite undeniable things.

All Substances Break Up Alternately Into the Same Electrons—the Basic Material of the Universe.

But facts more revolutionary and sensational were yet to transpire. It was found that, no matter what substance was used as negative electrode—no matter what foundation-stones were used—the electrons were always exactly the same, had always exactly the same mass, the same velocity, the same electrical charge. One might have expected that even if the atoms of zinc, and carbon, and platinum did break up, the fragments would be of different size and show different characters. But no; all the electrons, from whatever their source, showed identical characters. There could be no doubt, then, that Faraday's prophecy was fulfilled, and that Sir William Crookes was right in his opinion that these electrons were the basic material of the universe. If atoms and molecules differed from each other, they were the same at bottom, and the differences must be due only to different dispositions of the electrons composing them.

Soon it was found that identical electrons were generated by glowing metals and carbon, by burning gases, by metals under ultra-violet light. The atoms, therefore, in almost all matter, can be easily broken up to some degree; and the scientists who had considered the peculiar spectra found in the sun and certain stars to indicate atoms breaking up under great heat have been justified in their bold hypothesis.

The sun, which contains large quantities of glowing carbon, must be a great source of negative electrons. Issuing from the sun with the prodigious velocity we have stated, they speed across space and bombard the upper layers of the atmosphere.

The Aurora Borealis a Hail of Electrons on the Boundaries of Our Atmosphere

Now, the earth is a mighty magnet with North and South Poles; and even as the electrons in a vacuum tube can be deflected by magnetic force, so these electrons that pelt the outer atmosphere are deflected towards the poles. Further, it is likely that they signify their activity there, even as they signify their activity in a vacuum tube, by causing a phosphorescent glow. At least, there is good reason to believe that the beautiful shimmering light of the Aurora Borealis is caused by a hail of electrons on the boundaries of the atmosphere in the higher latitudes. Ninety-three million miles or so flash the tiny electrons, assisted on their way—it would seem—by the pressure of the light of the sun, for it has been proved that the light of the sun is able to exercise pressure, and when they strike the atmosphere they make the molecules of the gases there glimmer and glow. The gases on the top of the atmosphere are probably chiefly argon, krypton, xenon, and neon, and the theory is much supported by the fact that, if we put these gases in a vacuum tube, we can produce a miniature Aurora Borealis with beautiful rosy and green tints.

All down the centuries men had been searching for a basic material, and all the time the sun had been bombarding the world with it, and its banners had been waving in the sky. Even the tails of the comets had testified to it, for there seems good reason to believe that the tails of the comets are made to point away from the

sun chiefly by the vigorous assault of the flying electrons.

Now we must realise the deeper identity in superficial difference. Now we must realise that gold, and silver, and lead, and copper, and oxygen, and chlorine are all made of the same material, and that the differences between them are simply due to a difference in the number and in the behaviour of the electrons which go to the making of their atoms and molecules.

Every atom is supposed to consist of electrons flying at tremendous speed in more or less circular orbits, and held in their orbits probably by positive electricity, And even as the world would fly off at a tangent from the sun if the grip of gravitation were relaxed, so do the electrons in certain atoms fly away when the bond that holds is loosened or broken by such energies as heat, or ultra-violet rays, or electricity. In the disruption of the atoms their constitutional radical identity is revealed.

sented by a sphere an inch in diameter, the diameter of an atom of matter on the same scale is a mile and a half. An atom is not a large thing, but it is composed of electrons, and the spaces between them are enormous compared with their size—as great relatively as are the spaces between the planets in the solar system."

At first sight it may be difficult to understand how atoms can be hard and impenetrable, as they undoubtedly are, if they consist of particles with such distances between each. But a little consideration will show that it is just a question of speed. The electrons fly so fast that they seem to be everywhere at once. A few hundred grains of sand flying about inside a church with the speed of electrons would make it as impenetrable as a diamond. We do not even require to assume that electrons are hard, for even soft things become hard if they go fast enough; and modern science considers that hardness is merely softness in rapid motion.

A SOFT CANDLE SHOT THROUGH WOOD KEPT RIGID BY THE RAPID MOVEMENT OF THE ELECTRONS WHICH MAKE IT UP

The number of electrons in the atom is supposed to increase with increase in the atomic weight of the element. Thus in hydrogen there are supposed to be a thousand flying electrons, and in mercury no less than a hundred thousand.

It might be thought that in such an infinitesimal thing as an atom there could not be room for such miniature solar systems, but, according to the calculations of scientific men, there is abundance of room, and the spaciousness of the atom has been illustrated in various striking ways. "If," says one writer, "we imagine an ordinary church to be an atom of hydrogen, the electrons constituting it will be represented by about one thousand grains of sand, each of the size of a period, dashing in all directions inside, and filling the whole interior of the church with their tumultuous motion." Again, "If an electron be repre-

"It is probable," says a scientist, "that matter owes its rigidity only to the rapidity of the rotary motion of its elements, and that if this movement stopped it would vanish instantaneously into ether without leaving a trace behind. Gaseous vortices animated by a rapidity of rotation of the order of that of the cathode rays would in all probability become as hard as steel."

But, it may be said, though we have discovered that electrons released from atoms fly at a tremendous speed, what reason have we to believe that they fly at such a rate *within* the atom? Our reasons for our belief in the intra-atomic speed of the electrons are just that this intra-atomic energy explains certain properties of the atom, and that the energy of the electrons outside the atom cannot have started *de novo*. To this point we shall return when we come to the radio-active metals.

At all levels that man can reach, on or in the earth, living creatures abound, or have abounded. This picture shows twenty separate types of life—in the air, on the earth, in the water, and under the earth.

THE ASCENT OF LIFE

**The Growth of the Master-Thought of Evolution—
Pioneers who Felt Their Way to a Great Truth**

THE STORY FROM BUDDHA TO LAMARCK

We shall not do justice to the doctrine of organic evolution nor to ourselves unless we survey very briefly the history of the idea, and the names of its pioneers—one, at least, of whom started a great controversy which rages again to-day after nearly all men thought it settled. If we realise that the alternative to evolution is "special creation," we shall see that there is no real alternative at all, for any who will think; and so far is it from being true that evolution is the new idea, replacing what has stood for so long, that indeed evolution is the ancient doctrine, from which that of "special creation" was a local and temporary aberration, due to the influence of a race great in religion and morals, but not in philosophy.

The range of those whom we shall here call the pioneers of evolution is from Heraclitus of Ephesus, Thales of Miletus, and Gautama the Buddha, who all lived about the sixth century before Christ, to the Frenchman, Jean Baptiste de Lamarck, whose great work was published just over a century ago. We should encounter a great variety of speculation if we were to make our history detailed; and while most of it would be exceedingly vague, some little portion, and that the latest, is a circumstantial and specific theory, which is entitled to definite scientific rank, whether we be neo-Lamarckians or not.

The beginners were very vague indeed. Heraclitus was called the "dark," because his utterings were so obscure. Thales thought everything evolved from water. Buddha's teaching was, in one aspect, more definite, and as the basis of a great system of ethics it is worthy of our comprehension. In Buddha's view, as in ours to-day, all the forms of life are essentially one. The highest forms, which are human, find the reward of goodness in a Nirvana, which means re-absorption into the infinite being. But if they fail in virtue they become degraded, and continue their existence in the life of, say, a dog or a pig. Such humbler forms of life are thus to be looked upon as capable, in the future, of higher things. They may ascend; and, more on account of what they may become than on account of what they are, we must regard them as sacred, and take no life at all. The evolutionary doctrine of the ascent of man is thus clearly implicit in the teaching of Buddhism.

Neither at this nor at any later time have men in general found any difficulty in believing in "spontaneous generation" so-called—in the evolution of life from the lifeless. The denial of that belief, by a remarkable paradox, is reserved for the present age, the first to place the general doctrine of evolution on a secure basis. Aristotle believed in the spontaneous generation of young crocodiles from the mud of the Nile. There are passages in the writings of the great Greek which suggest that he had the modern idea of the evolution of species, even in a kind of anticipation of the Darwinian form. Undoubtedly we must call Aristotle the founder of the science of life, the "Father of Natural History," and the "Master of those that know." He studied at first hand, so far as he could, the forms of life, and was clever enough to see that sponges are a kind of animals, as we now know them to be. He thought that the earliest forms of life would be very simple and soft, and that from them animals and plants, each on the same principles, and neither of them by mere chance, must have sprung.

Last, before the modern age, we come to the unique figure of the Roman poet and philosopher Lucretius, whose poem "On the Nature of Things" will be a classic to

the end of time. He definitely declared the spontaneous and natural origin of life from the earth, " under the influence of rain and the heat of the sun," " wherefore the earth with good title has gotten and keeps the name of mother." Lucretius also accepted the idea, of which Empedocles seems to have been the real originator, and which we now think of as distinctively Darwin's, that many races of living things have made a bid for existence, but " have died out, and been unable to beget and continue their breed."

The Writer who First Used Thoughts that Startled the World Twenty-five Centuries Later

Empedocles, the Sicilian philosopher of the fifth century B.C., who is supposed to have committed suicide by throwing himself into the crater of Etna, and on whom Matthew Arnold has written a great poem, is therefore to be acknowledged as the first to state the theory which, in Darwin's exposition of it, shook the world of thought to its foundations nearly twenty-five centuries later!

The Jews, not great in philosophy, had other ideas of the origin of living beings, ideas which they had inherited from Babylon, and which are still taught to our children to-day. Those ideas came to be regarded as essential, not to Judaism, but to Christianity: and thus it is that, after Lucretius, we hear no more of the theory of evolution for many long ages. To the name of the evolutionist Bruno, murdered in 1600, we pay homage; and then pass, a century and a half later, to the illustrious thinker of Königsberg, half German, half Scotsman, named Immanuel Kant, to whose mind, in its youth, the reading of the mighty poem of Lucretius suggested what we now call the nebular hypothesis of the origin of the solar system.

The Wonderful Forecast of Modern Developments of Thought Made by Immanuel Kant

Kant was only just over thirty when he published his " Theory of the Heavens," in which he included what we now call the theory of organic evolution. He observes how so many animals seem to be built on a common plan, not as regards their skeletons only, but in other particulars. This, he says, " strengthens the supposition that they have an actual blood-relationship, due to derivation from a common parent, a supposition which is arrived at by observation . . . extending from man down to the polyps, and from these even down to mosses and lichens, and arriving finally at raw matter, the lowest stage of Nature observable by us. From this raw matter and its forces, the whole apparatus of Nature seems to have been derived, according to mechanical laws (such as those which resulted in the production of crystals); yet this apparatus, as seen in organic beings, is so incomprehensible to us that we feel ourselves compelled to conceive for it a different principle."

The Frenchman Buffon, a contemporary of Kant, must also be named, before we come to one whose name, at least, is familiar. It is to Buffon that we owe the celebrated idea, which may very well be true, but an idea very dangerous to enunciate in his day, of the spontaneous evolution of life in the water of the Polar ocean, unthinkable ages ago. As for existing forms, he was clearly an evolutionist. He suggests that the horse and the ass, as also the ape and man, may have a common ancestry; he recognises the presence of what we should now call " ancestral relics " in the bodies of various creatures, useless and inexplicable except upon the theory of descent; and he assumes that species may be changed, in the course of the ages, so as to become quite different from what they formerly were. His idea of the mode of action that produced such changes is worth quoting, because that is what, in our day, we want to understand. He speaks of species " being perfected or degenerated by the great changes in land and sea, by the favours or disfavours of Nature, by food, by the prolonged influences of climate, contrary or favourable."

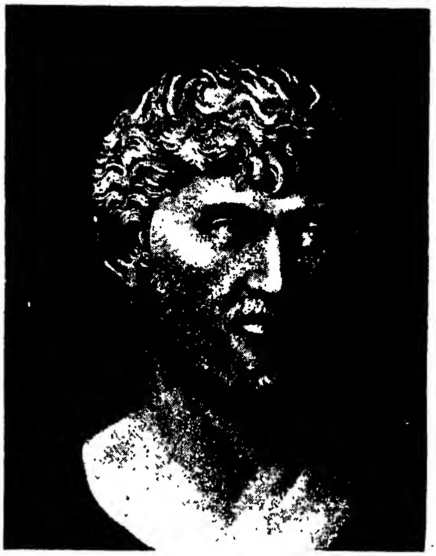
The Earlier Thinkers Saw Evolution as a Fact, but Failed to Trace its Methods

No hint is here, be it noted, of the Darwinian—or Empedoclean—idea of natural selection, but the author does advance more or less definite suggestions of possible ways in which species may change. And here we must note the important historical fact that the description of organic evolution occurs over and over again, in the work of real thinkers, for two millenia and a half, but the explanation is habitually lacking. The theory wanted something to make it seem rational and intelligible to everybody. And men of science want the explanation no less, for they have only to think of the eye, for instance, and the processes which could have formed it, in order to perspire with anxious doubt and wonder, as Darwin once confessed he did when he tried to account for its evolution. All these men we have mentioned were noteworthy, because they declared the fact to be what it is, but we look in vain to them for the

sorely needed explanation. In the quotation from Buffon we find real suggestions of a kind, but they are too vague and general in statement; and, indeed, the present era in biology practically begins a few years ago, when experimentalists have set to work to see what influence these factors suggested by Buffon a century and a half ago really have.

Erasmus Darwin, the doctor of Derby, was a follower of Buffon, and tried, in poetry and prose, to state the new ideas. Like his predecessors, he could effectively criticise the doctrine of "special creation," and could suggest the alternative, but it was left to his illustrious grandson to make a partly effective search for causes. Yet Erasmus Darwin was a great and original thinker, who wrote words well worthy to sow the seeds of fertile doubt in the mind of his descendant. He surveyed the evidence of his time, and was prepared to find in it warrant for the theory that all forms of life have a common origin: "When we revolve in our minds the metamorphoses of animals, as from the tadpole to the frog; secondly, the changes produced by artificial cultivation, as in the breeds of horses, dogs, and sheep; thirdly, the changes produced by conditions of climate and of season, as in the sheep of warm climates being covered with hair instead of wool, and the hares and partridges of northern climates becoming white in winter; when, further, we observe the changes of structure produced by habit, as seen especially in men of different occupations, or the changes produced by artificial mutilation and pre-natal influences, as in the crossing of species and production of monsters; fourthly, when we observe the essential unity of plan in all warm-blooded animals, we are led to conclude that they have been alike produced from a similar living filament."

This brave thinker also saw reason to suppose that the evolution of plants preceded that of animals, and that man was derived from some "family of monkeys in which, accidentally, the opposing muscle brought the thumb against the tips of the fingers, and that this muscle gradually increased in size by use in successive generations."



LUCRETIUS, THE ROMAN PHILOSOPHER

As is pointed out by Mr. Edward Clodd, to whose historical researches the foregoing is much indebted, Erasmus Darwin gives us no hint of the idea of "natural selection," of which his grandson was to be the sponsor. That does not now seem so great an omission from the system of Erasmus Darwin as Grant Allen and Mr. Clodd have regarded it, for, as we shall see, that theory is negative and restrictive, not constructive. On the other hand, Erasmus Darwin clearly credits the idea of evolution which lays stress on the results of use, and their inheritance by offspring—a theory which was to be made famous, not long after his death, by the great man to whom we now come, and who may be regarded as the last of the forerunners of organic evolution, though there is much to be said for our friends across the Channel, who hold that Lamarck is indeed not the last of the forerunners, but is the veritable founder of our modern view. It is indeed probable that, in the course of years, when the limitations of natural selection are more clearly seen, and when, at the very least, we are no longer troubled by those who claim for it more than Darwin did himself, the claims and services of his great French predecessor may be more generously estimated, even outside his own country.

The way was prepared for Lamarck. Evolution was beginning to be in the air, and he had an immediate precursor in his own country, whose name is also worthy of mention, as well as the illustrious poet Goethe. Says Charles Darwin: "It is rather a singular instance of the manner in which similar views arise at about the same time that Goethe in Germany, Dr. Darwin in England, and Geoffroy Saint-Hilaire in France came to the same conclusion on the origin of species, in the years 1794–5."

It is impossible to improve upon Darwin's own account of the views of Lamarck, whom he calls "this justly celebrated naturalist,"

and so we may here quote it: "He upholds the doctrine that all species, including man, are descended from other species. He first did the eminent service of arousing attention to the probability of all change in the organic as well as in the inorganic world being the result of law, and not of miraculous interposition. Lamarck seems to have been chiefly led to his conclusion on the gradual change of species by the difficulty of distinguishing species and varieties, by the almost perfect gradation of forms in certain groups, and by the analogy of domestic productions. With respect to the means of modification, he attributed something to the direct action of the physical conditions of life, something to the crossing of already existing forms, and much to use and disuse—that is, to the effects of habit. To this latter agency he seems to attribute all the beautiful adaptations in Nature, such as the long neck of the giraffe for browsing on the branches of trees. But he likewise believed in a law of progressive development; and as all the forms of life thus tend to progress, in order to account for the existence at the present day of simple productions, he maintains that such forms are now spontaneously generated."


BUFFON, THE FRENCH ZOOLOGIST

We have already seen that the modern evolutionist cannot accept this tendency towards progress without some qualification. But as regards the rest of the theories of Lamarck, they require to be most closely scrutinised. For many years past they have been lightly rejected in this country by the majority, partly because of the influence of Darwinism, and partly because too many of us have only heard of the weak part of Lamarck's views, which are amusing and easily remembered, and have forgotten the rest. There is here confidently predicted a forthcoming appreciation of Lamarck in this country and everywhere, such as may surprise those who only know him by, say, his theory of the giraffe's neck.

Believing that the need or the want comes first, and then the structure which will satisfy it, Lamarck argued that many of the wonderful structures of living things are produced in response to what we may call the subconscious will of the creatures. One creature might want certain structures, and use them when made, and transmit them to offspring; another might prefer to be without certain structures, and in a similar way they would disappear. Thus Lamarck explains the long neck of the giraffe as developed by its feeding habits, and gradually increased, by a kind of snowball process, in successive generations. Similarly, half-erect apes tried to become erect, and finally man became so. Animals with long tongues, such as the ant-eater, have got them through stretching them, and webbed feet are similarly accounted for. On the other hand, the four-limbed ancestors of snakes, "having taken up the habit of moving along the earth and concealing themselves among bushes, their bodies, owing to repeated efforts to elongate themselves and to pass through narrow spaces, have acquired a considerable length out of all proportion to their width. Since long feet would have been very useless, and short feet would have been incapable of moving their bodies, there resulted a cessation of use of these parts, which has finally caused them totally to disappear, although they were originally part of the plan of organisation in these animals."

These ideas we now commonly laugh at, and explain the giraffe's neck by saying that, in the struggle for existence among young giraffes, those with naturally longer necks would tend to get most food and survive, and reproduce their like on the average. That is the Darwinian alternative to Lamarck's explanation. Whether it is any more credible, or any more supported by real evidence, is perhaps not so certain. Mr. Clodd, for instance, in quoting the above passage, refers to "an efficient cause of modifications," which "has placed his speculations in the museum of biological curiosities." But in what sense can the force of natural selection, which weeds out short-necked giraffes, be called an efficient cause of the production of long-necked

giraffes? The truth is that we are only just beginning to understand that the action of natural selection is not positive, but negative; and that it does not account *at all* for the positive fact of the origin of new forms.

The time is at hand when everyone will realise this, as the newer school of biologists do already, and then we shall be able better to appreciate Lamarck. To him, says Haeckel, "will always belong the immortal glory of having for the first time worked out the theory of descent as an independent scientific theory of the first order, and as the philosophical foundation of the whole science of biology." Indeed, this great and deep thinker, well entitled to call his book the "Philosophie Zoologique," clearly stated, first, the descriptive facts of organic evolution, including that of man, as we believe them to-day; and thereto he added a detailed explanation which, notwithstanding certain rather ridiculous attempts to account for everything, contains certain statements which may yet be found to be the profoundest truth of this matter.

DR. ERASMUS DARWIN

Lamarck believed in what Bergson calls the *élan*, the "thrust," the "go," of life; that it is, in Bergson's phrase, "more than anything else, a tendency to act on inert matter." He saw it as something which takes possession of matter for its own ends. He would have agreed with Mrs. Browning that "it takes a soul to move a body," and with Edmund Spenser that spirit makes body. In more technical language, he believed that function precedes and creates structure. He accounted for many structures by the want of them felt by animals, until that want was satisfied. That is a difficult doctrine, and in any case it can only apply to structures that can be affected by the will, and it cannot help us to understand the evolution of plants, which have no wills. But this is where Bergson's idea of the "original impetus of life, passing from one generation of germs to the following generation of germs through the developed organisms which bridge the interval between the generations," seems to help out, to widen and deepen, the idea of Lamarck. This passionate want and "go" of life becomes comprehensible in all living forms, not merely in animals that have conscious desires. It is an essential attribute of all life; and just as Lamarck accounted for certain structures as brought into being by the want of the animals which possess them, so Bergson's idea of the desire, the "thrust" of life in general expresses for him the fundamental cause of the variations which give rise to new species.

In this theory of Lamarck's we must sharply distinguish between the part which concerns the individual and the part which concerns the race. Lamarck seeks to explain the development of the individual largely in terms of its function, and its striving to express the life in it. Later we must see how far the modern study of germ-cells justifies or qualifies this view. But Lamarck adds to this a second proposition regarding heredity, a proposition concerned, now, not with the development of the individual, but with the evolution of the species, for he declares that the effects of development of the individual, its striving and achievement, are handed on by heredity to the next generation.

This introduces us to the question of the "transmission of acquired characters," as it is unfortunately and misleadingly called, which is the characteristic theory of Lamarck to account for evolution. Darwin accepted this idea, but found it inadequate, so that he supplemented this possible factor of evolution with a theory of his own; but Darwin's modern followers, the "neo-Darwinians," reject what he was content to accept. The controversy is now at its height, though many think it closed; and it has involved more confusion of thought and misuse of language than perhaps any other controversy of our times. Here we shall try to make the case clearer than many have left it.

There is no single form of words, least of all the "transmission of acquired characters," which will nearly cover the

variety and contrast of conditions which are discussed under this heading. We must try to distinguish them, even with the risk of error; for truth, as Bacon said, is more easily extricated from error than from confusion.

Let us first take the straightforward question of the effects of use and disuse. It is a distinctive part of Lamarck's theory —but *not* the whole of it—that these are inherited. Ninety-nine people out of a hundred take it for granted to-day.

Is the Strength of a Blacksmith's Arms Transmitted to His Son?

They assume that "long generations" of any particular habit will show themselves in the conduct of men, or that long generations of disuse will show themselves in atrophy and disappearance of the powers or the organs which have thus been neglected. Let us clearly understand what this part of Lamarck's theory is. Its business is to account for adaptation. We plainly see the structure and the habits of living creatures, animal and vegetable, exquisitely adapted, in many cases, to the conditions of their lives, as in the case of the neck of the giraffe and the length of its fore-limbs. The assertion is not a general one —say, that physical exercise in parents will improve the physique of the offspring; it is the assertion that exercise of, say, the arms of the blacksmith will involve a natural tendency towards stronger arms on the part of his subsequently produced children. And, similarly, the disuse of any particular structure will lead to its diminution, not merely in the individual, which no one can question, but also in the subsequently produced offspring of the individual.

The Fallacy that a Thing Beyond Conception is Impossible

Lamarck did not offer any explanation of the manner in which he supposed the effects of use and disuse to be inherited. A great argument against him, in recent days, has been that, on our modern view of the germ-plasm and the germ-cells, it is "inconceivable" that such effects could be transmitted. This is a thoroughly bad argument, unworthy of science. We cannot explain or conceive the explanation of gravitation, but it happens. Many things happen which we cannot explain; and to assert in advance that such and such would be inconceivable, and therefore does not happen, is simply to expose our powers of conception to criticism. If an instance of what Lamarck asserted were proved, there would be no difficulty whatever in inventing or conceiving theories to account for it. The neo-Darwinian argument about the inconceivability of the transmission of the effects of use and disuse must not here be employed. We shall find reason to reject Lamarck's belief on the only possible ground—that there is no evidence in favour of it.

As for theories, Darwin, who was *not* a neo-Darwinian, invented one which enjoyed fame for many years, and which has lately been revived, we may almost say, in a new form which is perfectly conceivable. Both Darwin's theory and the new theory of Prof. J. T. Cunningham are worthy of close attention. The theory of Darwin, which he called pangenesis, has nothing to do with the distinctive doctrine called Darwinism, but might more appropriately have been invented by Lamarck to account for his theory. We shall therefore deal with it here, once and for all.

Pangenesis, or all-genesis, was Darwin's term to express the theory that *all* the parts of the parent make contributions towards the genesis of the offspring.

A Remarkable Theory Advanced by Darwin to Account for Family Resemblance

Darwin supposed that, from every part of the body, there were given off tiny representatives, which he called "gemmules," and that each gemmule had the power of reproducing something like the part of the body from which it had sprung. By the blood-stream these gemmules were supposed to be carried to the reproductive glands, and there elaborated into what we call germ-cells. Thus the germ-cells would veritably be produced from the body of the parent, the hairs and nails, and muscle-cells and brain-cells, and so forth, each sending gemmules which would develop into corresponding structures in the new individual. If the future parent lost an arm, there would be no gemmules forthcoming to represent that arm in his germ-cells; and presumably, if the same accident happened to both parents, depriving each of, say, the right arm, the subsequent children might, on this theory, have no right arms, since the necessary gemmules would be absent from the germ-cells which gave rise to those children. That is an extreme case, but evidently the same argument would apply to the specially developed arm of the blacksmith, or the brain of the linguist, to the long-neglected "political instinct" in

THE GIRAFFE, THE LENGTH OF WHOSE NECK GAVE RISE TO THEORIES OF EVOLUTION

women—to use a modern illustration without criticism—or to any other instance of use and disuse. We assume, first and rightly, that use and disuse affect the development of organs and functions in the individual. Then, on the theory of pangenesis—which was Darwin's, though it would be misleading to call it "Darwinian"—the offspring ought to be correspondingly affected, owing to the greater or smaller number of gemmules contributed to their formation from the parts of the parental body in question.

This remarkable theory, which offers a complete explanation of the transmission of the effects of use and disuse, was subjected to deeply interesting experiment by Darwin's first-cousin, Sir Francis Galton, forty years ago. Galton argued that, on the theory of pangenesis, "the breed of a

race might be sensibly affected by the transfusion of blood from another variety." Here is what he says: " I argued, the blood which conveys these gemmules to the places where they are developed . . . must be full of them. They would presumably live in the blood for a considerable time. Therefore, if the blood of an animal of one species were largely replaced by that of another, some effect ought to be produced on its subsequent offspring. For example, the dash of bulldog tenacity that is now given to a breed of greyhounds by a single cross with a bulldog, the first generation corresponding to a mulatto, the second to a quadroon, the third to an octoroon, and so on, might be given at once by transfusion."

The Experiments that Proved One of Darwin's Theories to be Wrong

The experiments were made upon silver-grey rabbits, nearly half of whose blood was replaced by that of common lop-eared rabbits. " It was astonishing," says Galton, " to see how quickly the rabbits recovered after the effect of the anæsthetic had passed away. It often happened that their spirits were in no way dashed by an operation which only a few minutes before had changed nearly one-half of the blood that was in their bodies. Out of a stock of three silver-grey bucks and four silver-grey does, whose blood had been thus largely adulterated, and of three common bucks and four common does, whose blood had been similarly altered, I bred eighty-eight rabbits in thirteen litters without any evidence of alteration of breed. . . . I continued the experiments for another generation of rabbits, with equally negative results. Mr. Romanes subsequently repeated the experiments with my instruments, and they corroborated my own. So this point seems settled."

The New Knowledge which Shows that the Body Does Not Make Germ-Cells

We have carefully quoted Galton's own account of this matter, for a special reason, which has not yet been appreciated or noted in the present controversy. Many may suppose that these experiments of forty years ago are not worth recalling now, for no one believes in pangenesis. Certainly the theory must be abandoned. There is no evidence that the various parts of the body send any contributions to form, in their aggregation, the germ-cells. We have clear evidence, as the study of Weismann's work will show, that the germ-cells have an entirely different origin, and that, in short, they are not made from the body which shelters them. Further, observation and experiment show that not merely use and disuse but such crucial instances as the amputation of rats' tails for large numbers of generations produce no effect in the way of diminution of the tail, let alone loss of the tail, in the progeny.

But though Darwin's theory of pangenesis must be definitely abandoned, there are novel considerations before us to-day which plainly remind us of it. Every part of the body makes characteristic chemical products of its own. We know that certain glands, such as the thyroid gland in the neck, though they have no ducts or tubes leading away any secretion from them, yet have an " internal secretion," as it is called, which they contribute to the blood as it passes through them, and which is subsequently carried everywhere in the blood-stream. There is good reason to believe that what is true of the " ductless glands " is true of every organ and tissue. They produce, in association with their activity, special chemical bodies which they add to the blood; and, doubtless, the more active they are, the more they will produce.

The Value of Glands in Producing Chemical Secretions of Use to the Body

It can be proved, in several cases, that these chemical bodies have notable effects on various parts of the body, both as regards their development and their working. Thus the chemical secretion of the thyroid gland affects the development of the brain, that of a gland called the pituitary affects the development of the bones, and so forth. It is very plain that, as Prof. J. T. Cunningham has suggested, there is here scope for a theory which is not Darwin's, and which yet might furnish similar expectations to his.

For why should not the characteristic products of the life of muscles, say, passing into the blood, be carried by it to every part of the body, including the germ-cells from which future individuals will spring? And may we not suppose that the effect of a muscle-product might be to stimulate that part of the germ-cells which was destined, in its turn, to give rise to muscular tissue? Similarly, if a part of the parental body were never used, and suffered atrophy, it would not send the due quantity of its characteristic " internal secretion," to stimulate the corresponding part of the germ-cells.

We see that a theory may thus be framed; and at the very least it does the service of

disposing of the foolish argument that the transmission of the effects of use and disuse is "inconceivable." Here is one of the ways in which such transmission may be conceived to occur; and we are accordingly indebted to the author of the theory. But we must now see whether the facts tally with it.

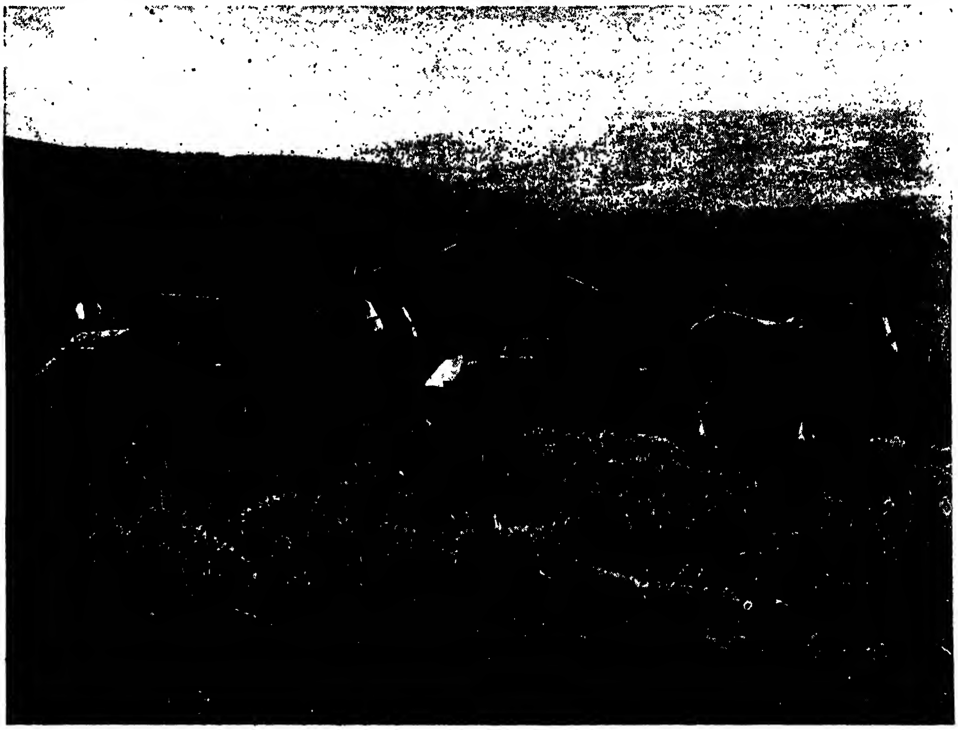
In brief, they do not. The theory would justly explain the facts if we observed them, but so far, in spite of decades of search, the facts are not to be had. That is where the modern importance of Galton's transfusion experiments lies. If Cunningham's theory were correct, we might reasonably have expected some influence upon the offspring which were produced immediately after the change in the parental blood. So far as those experiments go, the theory is thus not called for. The experiments of Weismann and others, conducted in great variety and with much patience, and endeavouring to obtain effects after the cumulation of many generations, have all been negative. Furthermore, the experience of mankind teaches the same lesson. The effects of use and disuse cannot be better studied than in mankind, for we can definitely observe such sharply contrasted cases as that of the offspring of always illiterate ancestors, and the offspring of long generations of highly educated ancestors. Similarly, we can observe the effects of disuse and self-control, so largely involved in the action of civilised life upon our instincts; and here again we find that disuse, while affecting the individual, has no effect upon his offspring.


AN EXTRAORDINARY EXAMPLE OF ADAPTATION—THE LONG TONGUE OF THE CHAMELEON
Photograph by W. P. Dando

This part, then, of the theory of Lamarck must be rejected. In so far as he asserted organic evolution to depend upon this factor, the verdict a century later must be that he was wrong. Nor need it here be insisted that, in rejecting this part of the theory of Lamarck, we are bound to abandon all those hopes of progress, snowball-wise, which were based upon the notion that the use of parental brains gave us an advantage when we came to educate their children.

But though this part of Lamarckism is now untenable and must be abandoned, he also held views as to the influence of climate, temperature, nutrition, and so forth, upon the parent which resemble the views of Buffon, already quoted, and which belong to a different category. So long as we speak ot "acquired characters," confusion will reign. The public has learnt that biologists reject the "transmission of acquired characters," and thereby are led to suppose that nothing which happens to the parental body can affect the offspring—an absurdity too wild to need refutation. We are deceived by words. Whoever first introduced the phrase "acquired characters," which is of recent origin, has innocently caused endless confusion, unfortunately not confined to the public, but shared by many medical men. The proper term to indicate the effects of function, or neglect of function—i.e., use or disuse—is "functional modifications." It is a clumsy phrase, but it is accurate, and was the term used by Herbert Spencer and others of his day. What modern biology, then, denies is the transmission of functional modifications—such as the biceps of the blacksmith, the linguistic faculty of the scholar, and so forth.

In the general view to-day this denial seems to bear upon such parental circumstances as change of climate, change of diet, chronic disease, involving the production of poisons carried everywhere by the blood, lead-poisoning, alcoholism, exposure to the conditions of slum life, and so forth. With all these and a host besides, the doctrine that acquired functional modifications are not transmitted to offspring has nothing whatever to do. Such cases must each be studied on their own merits. And so far are we from rejecting all the views of Lamarck, because we reject his theory on this point, that the observations of the last decade, especially in America, are beginning to teach us facts which exactly correspond to what Buffon and Lamarck asserted. We must therefore distinguish; and though we leave Lamarck, the last of the forerunners or the first of the prophets with a denial of one of his tenets, we shall find that we cannot long escape a serious consideration of other of his tenets, and we shall recognise that his part in the development of scientific thought has been underrated.



REAPERS THAT CUT AND BIND THE CROPS INTO BUNDLES

HARVESTERS THAT REAP, CLEAN, AND TIE WHEAT INTO BAGS

The photographs on these pages are by courtesy of the Ontario Government, the Canadian Pacific Railway, the Ivel Agricultural Motors, Ltd., Mr. W Reid, and Messrs. Wallace and Son

SEED-TIME AND HARVEST

How Each Year's New Wealth of Grain Keeps Sixteen Hundred Million People from Starvation

THE WILD UNUSED HARVESTS OF THE WORLD

By far the most important event in the year in every part of the globe is the harvest; and it becomes of more importance every year as the number of people in the world increases. It is curious that people and Governments are only just beginning to understand this. For the last fifty years or more the world has become "urbanised," as an American writer said. He meant that the minds of people were centred on the town and the things of the town, so that they looked on life from a perverted and unnatural point of view. This urbanising of people's minds has been observable in almost every country of Europe, and in parts of America. Happily "the new world has come in to redress the balance of the old," and there are parts of the world—especially in our oversea possessions in Canada and in Australia—where harvest is all in all.

In several parts of Europe that flocking of the people away from the harvest-fields into the barren streets, a movement generally called the "rural exodus," is being arrested. In Denmark, where the Government has done more for agriculture than any country has ever done, people have gone back from the towns to the harvest-fields; and the same thing is just becoming apparent in Ireland. This means that seed-time and harvest are beginning to take their proper place again in the world.

They matter supremely. Should one year's harvest fail we should all be on the edge of starvation almost instantly. In England this appalling prospect is more real than in any other country, because England grows less food in proportion to its people than any other country. Indeed, there has never in the history of the world been a country which was so dependent for its daily food on other countries. If the seas became impassable, we should all be near starvation within two months. But everywhere man lives only on sufferance of the farmers, who are the world's rulers.

Very few people realise how vast and how vital harvest is. Even in England, whose wealth is supposed to come, and does in great part come, from her ships and her coal, the greatest wealth still comes from her harvests of food for man and beast. We also think of the United States as a country to which the oilfields and mines bring inexhaustible wealth, but oil and coal and gold are hardly worth reckoning in comparison with the harvests. It is a striking idea that one year's harvest brings enough gold to build and equip all the great railways with their thousands of miles of metals and their tens of thousands of waggons and engines and rolling-stock.

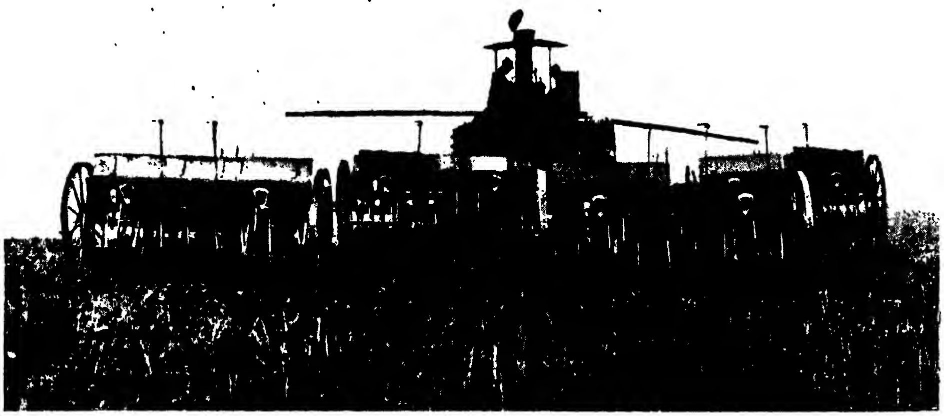
The mere figures of some few of the crops are enough to fill the imagination. The crop of maize, or, as the Americans call it, of corn, averages almost exactly 100 million pounds a year. The oat harvest comes to £40,000,000 or so, and the wheat harvest has amounted in some years to £100,000,000, though on the average it is smaller than the maize crop. The grain crops in all probability exceed 300 million pounds a year in value; but, in spite of this, the population is so rapidly rising that soon almost none of this will be exported, or become available for England and other countries which do not grow enough for themselves. It is calculated that in all 1,600,000,000 absolutely depend on the grain harvest for life. It can then scarcely be denied that harvest is the most important event of the year, even in England, and every nation should put forth its energy to make this harvest great and glorious.

It is curious that in England almost nothing of the kind is done. The Board of Agriculture, which is one of the great Government departments, has been supposed

only to prevent evils, to look into abuses, to arrest the spread of disease, and so on. It is only within the last year or two that it has ever considered the possibility of directly helping farmers in their business by any form of direct aid, beyond the issuing of leaflets. It is now helping small farmers to co-operate, and a special fund, called the Development Grant, has been set aside to assist the supreme industry of farming in a variety of ways.

To understand the meaning and magnitude of harvest it is necessary to go to America or Siberia or one of the newer countries, though harvest is wonderful enough in Egypt and in India, while in North America the whole energy of the country seems to mount to a sort of rage at harvest-time. Workmen pour out of the towns to the great farms. One million pounds has been spent in one season in one small region on agricultural machinery; and the whole great business is condensed into the shortest possible period. Nature has so arranged that this space may be very short indeed. Consecutive months of the year happen to be equally suitable for harvesting, ploughing, cultivating, and sowing. When all this is done the many workmen may return to the towns, the machines be set aside in shelter, and Nature left for the rest of the year to bring the seed to perfection.

It is worth while to remember in its various steps the process of an American harvest. The handful of labourers left on the great farm during the whole year are joined at the end of July, or about then, by the imported harvesters. Perhaps 200 of these men arrive on a 10,000-acre farm, along with a trainload of machines, at the end of July. As far as the eye can see the level plain is golden with ears, across which you can see a puff of wind travel as you can trace it over the sea. "Upon the great plains like those of California, an enormous harvester is used which has a cutting line 52 feet wide. These machines cut and thresh and stack the grain at the rate of 1600 sacks a day, and cover an area in that time of 100 acres. . . . The Bonanza farmer expects one machine to cut at least 250 acres, and three men are required for each of them. The harvest lasts from ten days to three weeks according to the weather." As soon as all the wheat has stood long enough in shocks in the field to mature—and this maturing is much quicker in America than in England—it is hurried to the great threshers, and from that moment is dealt with only by machinery, till it is made up in retail amounts of flour.



A PETROLEUM TRACTOR DRAWING FOUR DRILLS FOR SOWING SEED ON THE AMERICAN CORN-BELT

When the grain has gone away by rail or on the vast lake steamers, a great bonfire is made of the straw, which all think so valuable in England; and a week or two later the ploughs are on the land, and then the harrows, and then the drills dropping rather more than a bushel to the acre. On a good farm so much seed should produce about thirty-fold, so bountiful is Nature. It produces very much more on the average in England; for, though England is not a corn-growing country, English farmers are among the best in the world, and treat their ground generously.

It is both an interesting and important query how far the harvest of each acre may be increased by artificial aid, both in respect of cultivation and in improving the plants. The question of harvest always suggests

wheat, and yet, of course, there is no real reason why wheat should take so prominent a place. Potatoes, for example, produce starch just as wheat does; and man can make a good enough flour from bananas. But practically nothing has been found equal to wheat. It yields a large crop of food which is, unlike the potato, very free from moisture, and is therefore condensed. It is not very liable to disease, does not exhaust the ground overmuch, and is easily harvested.

It is believed that wheat has been cultivated from the earliest ages in the history of mankind. But without going back to the Stone Age, of which we have little more record than the record of the rocks, we know quite certainly that wheat was cultivated in Egypt before the Pyramids were built, and in Asia Minor before the Trojan wars and the mythical yet dimly historical days when Hector and Achilles fought and Ulysses wandered over the seas. It seems likely that farmers found the wild wheat plant on the slopes of the Caucasus, or on the plains of Mesopotamia, and, cultivating it on the wonderful plains which the Tigris and Euphrates rivers endow with permanent fertility, produced the seed which now gives life to the best part of the world.

Even rice is giving way to wheat. For centuries rice has been the chief harvest of the Japanese, and they have performed one of the miracles of the world in the way of intensive or close cultivation of the crop. They set out each plant separately in the field, and by their system of transplantation get such crops as Western farmers would think incredible. But as greater wealth has come to the people of Japan they have begun to prefer wheat to rice; and it seems almost an universal instinct in man to desire a wheat harvest if he can grow it. It is with the Japanese in their island to-day as it was with the English in their island when the forests were cleared away, and Alfred the Great issued the first agricultural pamphlet known in our history. Wheat, indeed, is the world's harvest.

IN THE MAGNIFICENT WHEATFIELDS OF TRAMPING LAKE DISTRICT, CANADA

The plant will grow in as great a variety of soils and climates as any useful plant. There are many places, no doubt—Newfoundland is one—where oats will ripen and wheat will not, but the range of wheat is very great, and the wheat grain is, of course, much richer in food. It is the custom of civilised nations to reject all the parts of the grain but the pure starch, which amounts to about 70 per cent. of the grain. The poor people have got into the habit of regarding this pure white flour as the finest and most delicate of foods; but gradually all people

are beginning to find out that the wheat grain with the germ, whose function it is in nature to eat the starch and grow from it, is a better food if left with its natural qualities and attributes. It is a most happy fact in Nature that this great food-giving plant will grow up in northern regions, as high as the 69th latitude in Norway, and hundreds of miles further north in Canada than used to be thought possible. It will flourish over 4000 feet high on southern mountains, and in some respects surpass in that rarefied air the great crops of the fertile plains.

The question arises whether after all these numerous centuries we can improve this harvest as the Babylonian farmers—if that theory be true—improved it after the first discovery. A very high authority at the English Board of Agriculture ventured recently to say that the value of the crop of each acre of wheat had been theoretically increased by 10 per cent. owing to the work of scientific workers at Cambridge University. He was no doubt led away by his enthusiasm into too high an estimate of recent improvements. But the yield of each acre has certainly been enormously increased within the last twenty years. A certain oat, called the "Abundance," brought out at the end of last century, undoubtedly yielded in favourable conditions 20 per cent. more than the older oats; and this variety has been improved in itself and improved upon by crossing with others.

Wheats have never been improved by quite so great a jump, but they yield much more than they once did. One reason is that you can buy wheats which suit the particular soil. You can buy them short in the straw, so that wind and storm will not flatten them; you can buy them with small "berries" or big; with grain of high quality and lower yield, or high yield and softer quality You can buy them for sowing in the autumn or for sowing in the spring. Each year multitudes of experiments are being made by men of science all over the world, and they promise great improvements.

Possibly one of the most interesting harvests of the world was to be seen in the summer of 1911 in Berkshire. After years of work, much spent in correspondence with people in all quarters of the world, some spent in travel, a professor of an agricultural college got together a collection of the world's wheats, what may be called the more or less original wheats. From this museum of wheats he selected the 200 best, and then the fifty best, and from these he grew the picked seeds. It is his opinion that from this collection of his he can produce at any time a wheat which shall have the best that any man of science can "create" by breeding.

He has bearded wheats, and red wheats and white wheats, and strong wheats, even so-called mummy wheats, in which the ears are branched. It is possible that his claim is true; for it seems to be even better to select the best seed from an ordinary


BUNDLES OF MAIZE PILED IN THE SUN TO DRY IN ONTARIO

plant than to try to improve the plant by making new plants or hybrids from it.

A beautiful instance of this may be given from Canada. 'When Canada was beginning to develop rapidly, and it was seen that her harvest was her chief glory, two men, one a millionaire, the other a high authority on agriculture, joined in a great partnership to improve the harvests. The one man supplied the ideas, the other gave the money. Among other benefits, a grand agricultural school or college was built, costing over a million pounds. But the plan which, perhaps, did more good than anything else, and was very much cheaper, was to offer a number of prizes to Canadian children for selecting the best ears from their fathers' or guardians' crops. These little collections were very carefully weighed, and all the grains counted; and the winners were those whose collection of ears weighed most, and had the best and most numerous grains.

This was only the beginning. Children and parents were gradually persuaded to grow, first of all, small plots, and then larger ones, from these specially selected ears. The effect of the spread of this system through Canada has astonished even the authors and designers of the plan. The children's prizes have probably brought millions of pounds of wealth to Canada; and it is no small thing for the youngest people of a country to feel that they are themselves sharing in its fine progress, not only to greater wealth, but to greater happiness and health of the world.

All plants have a tendency to grow smaller; and these cultivated plants which have been swollen beyond all comparison with the plants from which they originally sprang, relapse into smallness very rapidly. If you leave a pansy to seed itself in a field, it will become very small, the same in colour and size as the wild heartsease, within three or four years, perhaps within one. It is so with wheat. We have, therefore, to work well in order to keep our harvests up to their present level, as well as to improve them yet further. But this improvement is going on. There has been more advance made in increasing harvests during the last generation or so than perhaps for thousands of years previously.

We have been talking principally of wheat, but the improvement is yet greater in other plants, especially those grown in market gardens and in private gardens. But how the vegetables and grains are improved in size and quality will need a special discussion of its own. It has been shown how harvest on the great plain of America is condensed into the autumn, and

A THRESHING MACHINE DRIVEN BY AN IVEL MOTOR

the energy of Nature and the energy of men-workers are concentrated into harvest work through August, September, and October, when the grain is cut, threshed, and dispatched, and the ground cultivated and the seed sown, so that for nine months of the year a few men only are needed to watch the progress. This is the case in most of the great "granaries" of the world—in Siberia, as in America—though in the more northerly areas of the more bitter climates the autumn work of the American bonanza farmer is postponed to the spring, lest the winter, as sometimes happens even in England, should kill the young plants, and the frost attack them before they were protected by the kindly snow.

But in Europe, harvest—if the word be used in its wide sense—is not a quick and sudden event of this sort; and as the farmer's skill grows, and the need of making the fullest use of the ground increases, the period of harvest is drawn out into much greater length, the ground becomes a sort of factory in which the hands are almost always busy, and any slack time is deplored. Some very remarkable examples of the method of keeping the factory of the ground in motion have been seen lately on the best English farms. A Lancashire farmer, whose farm was recently given first prize in a competition organised by the Royal Agricultural Society, was able to grow two crops of potatoes off the same ground, one of early and one of late potatoes; and though the presence of the seed of the later crop made the harvesting of the early crop a rather slower and more costly affair, the double crop was a great source of wealth. Gardeners have long been used to work their ground in this way, but it is newer with farmers; and perhaps some day, as the ground becomes more and more valuable, the farmer will become more and more of a gardener. In Jersey, in the north of France especially, and now in Cornwall, the first potato harvest is gathered in the spring of the year, while in other places potatoes are left in the fields till November.

Again, the system of what is called catch-cropping is increasing in favour every year. By a catch-crop is meant a crop which, as it were, steals a part of the year. For example, when a farmer has harvested his early potatoes, he may sow rape-seed, which will give him a second harvest within the year in the shape of green food for his animals. In theory, at any rate, it is clearly a loss of time to keep a crop such as wheat growing all the year from October to the following August and September when it can be made to grow in rather less than half the time. You may sow a grain crop even as late as May, and reap it hardly later than the autumn-sown crops.

Of course, autumn sowing is Nature's way. She scatters the seed as soon as the plant has reached its maturity; and farmers find that, the earlier the crops are sown, the less, as a rule, they suffer from disease. Diseases are apt to come with the spring and summer, and only well-established plants are strong enough to resist. Yet Nature, too, sows in spring, or, rather, many seeds dropped at harvest-time remain dormant for one reason or another till a later time—it may be next spring, it may be several years later. So it is that spring sowing in some seasons and on some soils is more successful than autumn sowing. As time goes on plants of two sorts are bred, which make it possible to use the period between autumn harvest and the spring seedtime for a third or catch-crop. In the first place, wheats are now bred which are especially suited for sowing in the spring. Secondly, green crops are bred which give heavier yields and come to full growth earlier in

A PETROLEUM TRACTION ENGINE DRAWING TWO REAPING AND BINDING MACHINES ON THE AMERICAN CORN-BELT

the year. Thus harvests may become more and more continuous, and as the land produces more the well-being of those who work the land should be promoted in equal measure.

All this is only possible on certain soils. There are heavy lands where one harvest a year is perhaps likely to be the rule for many centuries.

It has been said that man has always to work to prevent the harvests relapsing and the cultivated plants returning to their wild state. He has also to strive against the inroads of weeds upon all cultivated land. The Canadians and Americans in the last few years have been forced to use special machinery to sift from the wheat weed-seeds that were at first unknown. But in considering the wonder of the harvest one has also to look at weeds as an example of the astounding fecundity of Nature. Many of the weeds are very little less valuable than the harvests which have supplanted them. Watch an Exmoor or a Shetland pony eating rough hay. You will see him pick out first the nettles. Is there any plant which is generally regarded as a more noxious or useless weed? Some of the weeds would be well worth cultivating, and agricultural reformers have recommended their growth as a regular harvest. Such weeds are hogweed and comfrey, both of which would yield a very heavy weight of harvest. But the energies of men are not exerted with half the earnestness in adopting plant life as in securing mechanical power.

THE GLEANER

Indeed, harvests are all about us, the hazels, the briars, the thorns, the trees, and the grasses giving harvests of fruit and leaf and stem and root. Science has selected the best of these—that is, those best suited to the needs of man—and Nature has pointed out the way how to guide them to yield the greatest value. If at any time compulsion were put upon us we could now make England, which imports so vast a proportion of its food, feed itself. It has been calculated that the county of Essex, built up as it is, could feed more than half London, as in the days when towns lived on the fields outside their walls. But such estimates as this lead to the whole question of cultivation of a more intensive, of a closer sort than is as yet possible on the farm.

The way of a seed in the ground is at least as miraculous as any of Solomon's four wonders; and if we could understand the progress of one such wheat-seed of the million sown it would give us as much knowledge as Tennyson suspected to lie in the "little flower in the crannied wall." There is not perhaps a great deal which is wonderful in the greater part of the seed as we see it with our eyes, for the bulk of it is pure food. In a wheat-seed or a bean—which are in structure and in their classification as different as two seeds could be—the bulk is food for the coming plant.

A wheat grain is for the most part starch, which lies as a storehouse for the plant just in the same way as the honey-bread and pollen that are buried by the single bee along with the egg. To see in the late spring the young bees coming up out of the ground is indeed almost an exact parallel to the coming up of the blade of corn. Both are buried, both are provided with a store of food, both devour the food as they develop; and, when they have so gotten strength, both use it to thrust themselves out of the ground. There, of course, the parallel ceases for the moment, though it may be resumed again in their later life.

THE END OF THE TRAIL—A PACK OF DOGS SUCH AS TOOK PEARY TO THE POLE

The Eskimo dogs, shown finely in this picture of "The End of the Trail," by Miss Maud Earl, are derived from domesticated wolves, and retain many of the characteristics of their ancestors, notably a blind ferocity which impels a whole pack to fall upon one which is attacked by another. But they have wonderful courage and endurance in harness, and they took Peary to the North Pole.

THE TAMING OF THE WILD

How Man has Subjugated Part of the Animal World, from the Obedient Dog Down to the Supercilious Cat

CAN HE EXTEND HIS ANIMAL CONQUESTS?

In the preceding chapter we have surveyed some of the aspects of human activity abroad which render man still dependent upon animal life. We may now take a nearer view of the subject by glancing round the home of a man in the United Kingdom. Ninety per cent. of the work of the farm and garden in this country is done by the labour of animals. The farmer must have horses; if he chooses, he may add asses and mules, but as a rule he does not so choose. He must have cattle and sheep, pigs, perhaps goats, and poultry. He must have dogs to help him with the sheep and to keep down the number of rats and mice in his barns and stables; and cats in the house for the same purpose. He will probably be proud to have a good flight of pigeons; and if he has a decorative garden he will perhaps indulge himself in the luxury of a few peafowl. He may have pheasants and other game-birds in his woods, all of which have been raised under artificial conditions.

Some of these animals and birds the farmer has to labour, some to yield him profit, some for æsthetic gratification. Their presence in his keeping is for the most part determined by the persistent law of supply and demand. There is a market for the produce of his farm—for his corn, for his fat beeves, for his titanic porkers, for the product of his dairy, for the eggs and delicate flesh of his poultry. He keeps all these things because there is a demand for them, or for that which they yield in labour or in the form of food and clothing. Strike out these animals and birds from our list, and of what value is civilisation, what are its possibilities? Civilisation would cease to exist but for the labour of animals. There could be no gathering together of vast numbers of people into civic assemblies: They could not be fed; they would be driven to roam as nomads in search of precarious bread. The population of Great Britain would drop from 45½ millions to negligible proportions if the country lacked animal food, or the food which is won from the soil by the labour of animals.

The extinction of our animals would strike our commerce dead at a blow, if only for one fact. There are three thousand coal mines in the United Kingdom; and in the bulk of these mines we are at present, as for generations we have been, absolutely dependent upon the strength of ponies and horses for haulage. Wonderful as are the achievements of machinery, we cannot have much mechanical haulage in many of our mines. The risk of explosion and loss of human life is too great for such a plan to be generally adopted. Therefore it comes to this simple fact: that the British Navy depends for its coal, and hence the Empire for its defence, upon the labour of a certain number of studs of Shetland ponies, New Forest ponies, and other small members of the horse tribe; and all our factories and iron foundries and textile works—all, indeed, of the great enterprises which give the British nation commercial pre-eminence—are driven to reliance, in the last resort, upon the same source of energy. Food resources also are governed, perhaps to too great an extent, by the supply of flesh substances; and boots and clothing respectively come almost entirely from the hides and wool of animals.

It is fair to ask what would have happened to the white man settling down in New Zealand as it was when Polynesia first sent her sons and daughters there to colonise the strange island-world, a thousand miles from anywhere. To make life supportable in conditions approximating to civilisation our colonist would have had to take with him horses, cattle, sheep,

rabbits, hares, poultry, dogs, cats, many birds to keep down insect pests, practically all the birds which gladden the heart with their song. For New Zealand was the one land in the world without domesticable animals. It had only small primitive reptiles, one species of frog, but never a mammal save two species of bat. Birds were the lords of the land, birds which, unmenaced by foes, developed vast bulk, and, in many instances, lost the use of their wings.

Australia was better off with its marsupial types, but there were no possibilities for man until the lowest of the human type, the Australian bushman, arriving as it were from the clouds, struck up a sort of alliance with the dingo. The colonist has had to take plants and trees and herbage for his cattle to New Zealand, but he has had to take bees also, to fertilise the blossoms of his fruit trees and for the flower of his clover, just as Japan has had to buy English and American fertilised queen bees to give her sweet apples and pears, to which before she was a stranger.

The Dog—the First Wild Animal that Man Succeeded in Taming

So far as we are able to read the history of the past in the remains found in the ancient kitchen middens, in cave deposits, and by such other evidences as are available, the order in which man drew upon the wilds was pretty much as follows: dog, pig, and reindeer; then, considerably later, and in irregularly successive periods, the sheep, cow, horse, goat, camel, elephant, yak; and the cat, apparently, last of all. There is no doubt as to the dog having been man's first animal friend. That we have seen already; and as the pedigree of this potent ally of the human race is dealt with on page 551 and succeeding pages it is unnecessary to go again over the ground.

We may leave it with just the reminder that all our domestic breeds are the descendants of wolf or jackal, or of both. The immense diversity of breeds would make this seem almost impossible had we not hosts of breeds of fowls which we know to be the descendants of jungle fowl, and almost as many breeds of pigeons, which we know proceed from a single species. Man may take credit for this diversity. It is due to his selection, sometimes unconscious, more frequently deliberate, that breeds have multiplied.

No fewer than 185 distinct breeds of domesticated dogs are now recognised; and so expert has the fancier become in evolving variants that there is no reason why the number should not be almost indefinitely increased. All the breeds fall into some half-dozen groups: wolf-like dogs, greyhounds, spaniels, hounds, mastiffs, and terriers, and in each division we get extraordinary diversity.

Take, for example, the wolf-like type. Here we have Eskimo dogs, which are mainly domesticated wolves, for our Ice Age contemporary regularly recruits his stock by introducing a wolf sire into his team. And, true to ancestral traits, these dogs, when famished, endeavour to devour their masters. The dogs of the more northerly tribes of Red Indians are wolflike in type; and the dogs of the Hare Indians interbreed with the coyote.

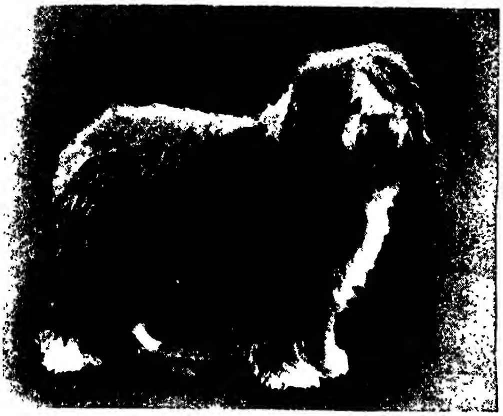
The Strong Affinity that Exists Between the Dog and the Wolf

The black wolf-dog of Florida, the sheepdogs of parts of Europe, and pariah dogs of India all bear close resemblance to the wolves of their several lands; while in South-Eastern Europe and Southern Asia it is to the prevailing type of jackal that the semi-domesticated dogs present closest affinity. The tiny pet Pomeranian is only a small wolf, with the Eskimo dog as nearest immediate ally. The large Pomeranians were formerly employed to hunt the wolf. The clever little Shipperke belongs to the same group, in which is also included another modern favourite, the Chinese "chow-chow." The sheepdog and collie, distinguished by extraordinary intelligence of a specialised bent, occur in the same division, but mark a distinct difference, in that their ears are, to a certain extent, pendulous, which never happens among wild dogs. The so-called wild dogs proper do not come into this chapter, having already been described.

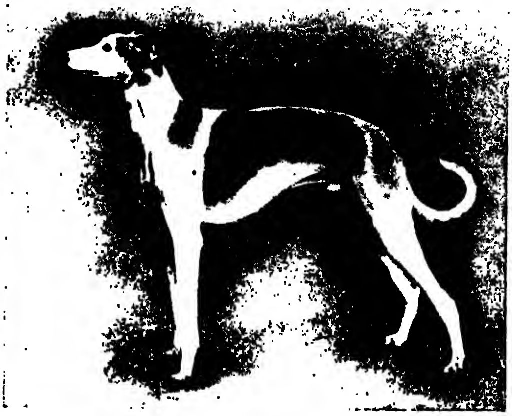
Why the Greyhound's Keen Sight Makes Up for Its Loss of Scent

The greyhound preserves the long, slender skull of the wolf, but has been bred right away from the ancestral type, so much so that it has lost the power of tracing its prey by scent, and hunts by sight. The reason for this is that in order to develop a long, pointed muzzle, enabling the dog to seize a small animal when racing at full speed, there has necessarily been a sacrifice of surface space within the cavity of the nose; in other words, the dog's nose is not big enough to contain the necessary olfactory equipment by which he should scent his prey. The breed at one time suffered in another respect from over-specialisation in pursuit of speed-giving qualities; it was

THE DESCENDANTS OF WOLVES AND JACKALS



SHEEPDOG



GREYHOUND

KING CHARLES SPANIEL

BLENHEIM SPANIEL

FRENCH BULLDOG

BLOODHOUND

BLACK PUG

NEWFOUNDLAND

COLLIE

From the wolf or from the jackal, or from the mixed union of both—that is the family history of every domesticated breed of dogs in existence, man's first allies against animal enemies. On this page are shown characteristic types of man's best friend in the lower animal world.

bred with jaws too weak to kill. Hence, this willowy creature had to be crossed with the bulldog to give it back the power of jaw which the breed had lost; and then, the missing characteristic having been regained, the bulldog strain had to be gradually eliminated until the due combination of power and endurance was secured.

The splendid Scottish deerhound is a rough greyhound; the slughi is the Persian or Arabian representative. The Afghan, the Italian, the Grecian, the borzoi or Russian wolfhound, and the Ibiza, of the Balearic Islands, are other breeds. The last-mentioned variety is interesting from a tradition that these dogs originated in North Africa, and that the animals of to-day are the descendants of the prick-eared greyhounds which we see depicted in so many Egyptian paintings and sculptures.

The Many Valuable Qualities that Man has Developed in the Dog

All these dogs were originally devoted to the chase or to labour—some to haul conveyances, some to hunt wolves, others to catch game for their masters. The same rule applies to the development of the spaniel breeds, some to catch game, some to find it, some to retrieve it upon land or from the water. From an intercrossing of collie and greyhound, or deerhound and collie, or any pair of these four, we get the lurcher. It is a special blend of qualities, giving the speed of the greyhound with the sagacity of the collie or sheepdog; and the possession of such a dog makes any man in humble circumstances the terror of the gamekeeper.

The spaniels are divided into four breeds, and from them have sprung the setters, dogs which find game, and instantly come to rest, on guard, as it were, a guide to the gunner. The pointer, which does this work more perfectly, is quite a different dog, descended from a Spanish breed, but modified out of all recognition. The original dog, though possessing marked ability for tracking and indicating the presence of game, lacked speed and stamina.

How the Pointer has Been Specially Modified for Its Special Work

The blood of the greyhound was introduced for speed, that of the bulldog for strength, but the results were unsatisfactory. Then a cross with a lighter type of foxhound was tried, with excellent effect, except that the resultant pointer was wont to track by foot-scent instead of by body-scent. This defect was serious, for unless a bird had walked, the dog could not trace it. This difficulty was overcome; the foxhound's habit of tracking foot-scent was eliminated, and the ability to detect body-scent was introduced. The new breed had to be taught anew to "point," but the characteristic soon became instinctive and hereditary, so that a dog of this breed has been known to stand pointing for hours until quite exhausted. The Dalmatian, once a popular carriage-dog in England, is employed as a pointer in Dalmatia.

These details are interesting, as showing how men have gained new breeds by combining several others, taking a quality here and a trait there, and stamping out weaknesses. Domesticated animals in the hands of the experts are as plastic as plants in the hands of the botanist. The same idea is to be traced in all the old-established breeds. Utility was sought in all. The Newfoundland, with a height of 30 to 31 inches at the shoulder, is a glorified spaniel, specially bred with reference to courage in the water, and as a life-saver. The retriever is a product of the Newfoundland and the water-spaniel or setter, specially adapted for retrieving game on land.

The Hounds as the Great Example of Endurance and Speed

The pointers, already mentioned, belong to the hound group, at the head of which stands the bloodhound, a dog at one time pre-eminent for its power of hunting by foot-scent. The bloodhound nose seems, however, sadly to have deteriorated—in England, at any rate—for upon the occasions during recent years when it has been called in to help the police, it has been almost uniformly unsuccessful. In fairness to the hound it should be noted that, as a rule, its services are not requisitioned until the police are quite baffled, by which time the scent may have been obliterated. The staghound is descended from two extinct breeds, and the foxhound is a descendant from one of these, either the old southern or northern hound, with, perhaps, some intermixture of a different breed. The modern hound is a triumph for the expert who seeks endurance coupled with speed.

Even the dachshund, with its legs seeming all awry, has its use—it is employed in hunting the badger in Germany. Its English representative was the turnspit, the dog which, enclosed in a circular cage, joylessly turned the spit that cooked the dinners of Merrie England. The mastiff and the bulldog belong to the same group, the latter having been evolved from the former purely as a fighting machine. In bull-

baiting days the English bulldog was the fiercest of dogs, but latterly, its occupation gone, it has lost much of its ferocity, without any special addition to its low standard of intelligence.

Another notable animal in this group is the Great Dane, or German boarhound, the largest of which may reach a height of three feet at the shoulder. The Great Dane still hunts the wild boar and stag in the Black Forest. Its degenerate kinsman, the pug-dog, is ugly enough to recall the bulldog's head, and its hide is still reminiscent of the mastiff, but this is one of many instances of breeding run mad. The old mastiff was judged on its ability to tackle a savage animal; perfection in its descendant, the pug-dog, resides in the curl of its tail, and in the number of hairs contained in black moles growing on each cheek.

The powerful dog which guards the Tibetan's flocks and camps from wolves and robbers, and helps as a beast of burthen, is classed among mastiffs; although its coat is long and thick. But one high authority holds that this dog, with the splendid St. Bernard, the friend and rescuer of travellers lost in the Alps, is descended from the great, mastiff-like dog of the Greeks and Romans.

The terriers have, in the main, the hunting instinct, even the poodle, whose coat we clip into ludicrous designs, making a capital water-dog and retriever. But many of the breeds have degenerated into mere fancy examples, and are valueless except as evidence of man's power to attain surprising variations.

The whole story of the dog family in a state of domesticity is instructive. for here we have all this variety of breeds evolved from one or two primal stocks. And no matter how extravagantly unlike its ancestors, every dog that lives can be traced back to a line of animals which once had a serious purpose in the life of man

Next to the dog, man took the pig, and domesticated wild swine not greatly differing from those found wild to-day. It was a big, long-legged animal, thin, with formidable tusks, which only slowly matured. It started its career from the same ancestry as the peccary and the hippopotamus. At first it must have been in dentition more like the pig of to-day than the heavily tusked beast we now find in the wilds. The tusks were the pig's weapons of offence and defence; and these developed, in course of time, as did the weapons of all other wild animals.

Whether the British pig comes from the European wild swine or from the Asian, or from both, cannot now be decided. The evidence goes to suggest that all the domesticated pigs arose originally from the wild pigs in their own locality, but that, since the first domestication, there has been an intermingling of the various breeds of these animals in a state of domestication. Just as dogs interbreed with the wild of their kind, as we have seen, so in India to-day the domesticated pigs run free, and interbreed with the wild boar of India.

A GROUP OF BISON AT THE ZOOLOGICAL GARDENS, LONDON

We are so accustomed in this country to seeing pigs confined to filthy sties that we regard the animal as instinctively unclean and dull of intellect. The fact is, however, that the pig is little different in its likes and dislikes from the hippopotamus. It is intolerant of heat, and if at liberty will take its mud bath, in order to cool and free itself of insects. The horrible condition of the sty in which it is habitually kept is not such as the pig would choose for itself in a state of nature.

In intelligence the pig ranks higher than some animals to which more attention has been directed. It is one of the educable animals. Of this we have evidence, apart from the show performance of various "learned pigs." More than one sportsman has taught pigs to hunt, and has declared

them more easily educated to their work than dogs.

But the fact which matters to the average man interested in pigs is this: that this animal is the most economical meat-making machine in the world in the hands of a man who knows his business. From a given quantity of digestible food it will produce twice as much weight as can be gained in beef or mutton by ox or sheep. It is not in Ireland alone that the pig is the "gentleman who pays the rent"; in many a poor English cottage one pig provides the only meat supply of a family for the winter, and its fellow satisfies the landlord's demands.

The Strange and Repulsive Cousins of the Domesticated Pig

Seeing that even domesticated pigs in warmer climes than ours, allowed to roam in summer time at will, ascend to a height of nine thousand feet in the mountains, it is not surprising to find that the true wild pig, the so-called red river-hog, which ranges from South to Central Africa, though its proper place is in the marshy fringes of rivers and swamps, is equally at home upon the mountain slopes. Africa possesses one of the most repulsive of the pig family in the warthog, a creature characterised by large warty protuberances on the sides of the face. The eye-teeth of the upper jaw are thrust out to form huge tusks, curving upwards, while those of the lower jaw form similar but smaller tusks.

The strangest of all the family, however, is the babirusa, a name given by the Malays, and signifying "pig-deer." In this pig the upper tusks are not produced from the jaw, but from near the middle line of the face, whence they curve backwards until the points meet the face. The lower tusks have a similar upward curve, but do not follow the line of the upper pair back towards the face. This curious arrangement of tusks has suggested to the native of Celebes and the neighbouring island of Boru the appearance of a deer's antlers, hence the name which they have bestowed upon the babirusa.

The Hairy Sheep with which Man First Set Out as a Flockmaster

The sheep was domesticated by man at the beginning of the time in which he really began to establish himself as an owner of stock. There is no definite evidence as to its origin. A true wild sheep existed in England at one time, and resembled, it is thought, the Armenian mouflon, but we have yet to trace this animal to days preceding the beginning of the glacial epoch. Probably the sheep and goats arose fro antelopes more or less nearly allied to th gazelles, while cattle, which are their senior geologically considered, and have affiniti with the sable antelope and oryx, ar considered to have descended from ancestr allies of that group.

The dog would help man to captur sheep, for man unaided would have littl chance of securing these animals excep by means which would lead to their bein badly maimed by pitfall and trap. Whethe it was the flesh of the animal or its coa that he required in particular, we do no know. It was not until the nineteentl century that we mastered the secret o breeding a sheep that yielded fine woo and fine flesh together. The huge fleec which we now associate with sheep is, o course, the result of careful breeding Allowed to run wild, the sheep shows a tendency to revert to hair rather than wool and this is the case even with domesticate sheep on the islands off the West Coast o Ireland and in the island of St. Kilda. Onc he had become the owner of sheep, early man was on the way to prosperity.

The Valuable Results Accomplished by the Modern Breeder of Sheep

The animal is prolific, its flesh forms a admirable food, its skin would yield hir leather; its hair or wool gave him clothing its milk would possess a high value as food and it is not impossible that the animal was pressed into service as bearer of packages, as is still the case to-day in the East The modern sheep-breeder has done wonders We have nearly thirty well-known breeds to-day, divided into three groups—long wools, short wools, and mountain breeds. As each breed has its special value according to locality the names may be of interest, though we have not space to touch on characteristics. We have, then, in the long wools, the following breeds: the Leicester, Border Leicester, Cotswold, Romney Marsh, Southdown long wool, South Devon long wool, Wensleydale, and Roscommon. The short wools are made up as follows: Southdown, Hampshire Down, Dorset Down, Shropshire Down, Suffolk Down, Dorset and Somerset horned, Ryeland, and the Oxford Down. The mountain breeds comprise the Cheviot, the Scotch blackface, the Herdwick, Limestone, Lonk, Exmoor, Dartmoor, Welsh Mountain, Kerry Hill, Radnor or tanface, Clun Forest, and the Penistone. Of the value to-day of domesticated sheep it is unnecessary to speak. Great Britain alone possesses over 31 million of these

animals, while Australia owes more of its prosperity to sheep than, perhaps, to any other source. Wild sheep of various species are still plentiful, in Europe, and in Asia, northwards of the outer range of the Himalayas, while the Punjab and Sind have a local race, and the Rocky Mountains have their famous bighorn.

The dividing line between sheep and goats is not invariably sharply defined, but two rough-and-ready distinctions are observable in the fact that no sheep, domesticated or wild, is bearded, while most goats are; and male sheep lack the strong odour which characterises the male goat. The goats inhabit hillier country than the average wild sheep, and there is an important difference in the feeding habits of the two groups: the sheep grazes; the goat prefers the young shoots of trees and shrubs. The catholic tastes of the goat in the matter of diet are notorious; and the fact that it can thrive where any other domesticated animal would starve is mainly the reason why this animal is becoming more and more the poor man's cow, in countries or districts where Nature is so niggardly in her supply of ordinary pasturage as to clearly mark an economic margin between the barren and agricultural lands.

There is one point as to the diet of the goat which has the defects of its virtues. In days of old the animal was regarded as the special creation of the devil, and because it destroyed the vines it was sacrificed as a propitiatory offering to Bacchus. According to Carl Vogt, the goat is the most destructive of all creatures in forests. "The old seats of civilisation, namely, the countries round the Mediterranean, owe the destruction of their forests, the nakedness of their mountains, and the inevitable consequences of that condition, the dryness of the climate, to the devastation of these animals." It is quite impossible to permit goats to run at large where any green thing of value is growing. They spare neither shrub nor hedge, neither tender shoot nor even the bark of trees. But, with all its faults, the goat has a high value, in respects of its skin for the furnishing of our morocco-bound books and our gloves; and primitive peoples of the East still find it indispensable for the making of their tents and rough cloth. The wild species include many magnificent animals, notably the tur, the Spanish species, and the typical wild goat. These are chiefly of interest to sportsmen, for they are not to be approached by men of the plains. And it is to be said for the goat-hunter that at any rate he must take his life in his hand to get at his quarry, for there is no finer climber of giddy heights and precipitous rocks than the wild goat on the mountains.


THE BUFFALO OF SOUTH AFRICA

Still following the order in which the animals were domesticated, we come next to cattle, including the bison, the buffalo, etc. Our domestic cattle, of which, by the way, the United Kingdom at present possesses some 11¾ million, are descended from the aurochs, which was afterwards crossed with cattle of the urus family. The aurochs, like the bison, a gift from Nature, roamed all over Europe and was not exterminated as a wild animal until after the first quarter of the seventeenth century. Its nearest living representatives are the half-wild park cattle of which small herds survive at Chillingham, Cadzow, Lyme, and Somerford, and at Woburn Park, where the Duke of Bedford is making a praiseworthy effort to preserve the last of the famous Chartley herd.

Cattle have meant perhaps more to man in the past than any other animal. From these he had milk, butter, cheese, leather, beasts of burthen, and steeds for the first plough ever devised. Man's selective skill has been abundantly manifested in the breeds of cattle that now appeal to the

connoisseur. The ancestral cattle were animals possessing enormous horns—some with a span of fifty inches. But, thanks to careful breeding, the shorthorn to-day is more numerous than all the other breeds of British cattle put together.

The humped cattle of Africa and India are descended from a different ancestry from that of European cattle, that of our dependency being derived, it is believed, from the bantin of the Malay countries. The humped cattle of China and Madagascar may have had, it is thought, an African origin. The gaur, a splendid animal of India, the largest specimens of which reach a height of six feet at the shoulder—eight inches higher than a good brougham horse—has never been domesticated, unless reports as to the attainment of this object by certain tribes on the north-eastern frontier be credited. The gayal, however, only slightly smaller than the average gaur, is kept in a state of semi-domestication in Assam and elsewhere, but it is of interest to note that herds of these animals so kept, roaming at will, are said to interbreed with the wild gaur.

The Vanished Herds of Bison that Fertilise Our English Rose Gardens

Use and wont have caused us to accept the term "buffalo" for the mighty animal which once roamed the prairies of North America, but that animal was a bison. It remains but little more than a memory in the New World. The vast hosts of these creatures, estimated to number in the north 4,000,000 and in the south-west a million and a half, were ruthlessly butchered to feed the builders of the railways and to provide pemmican for the men of the Hudson Bay Company. Their bones littered the plains in such numbers that, when bison were no more and bad days came, the starving Indians turned an honest penny by collecting these bones for conversion into artificial manure. And many an English rose garden in the past has owed its fragrance to the pulverised remains of these one-time monarchs of the rolling prairie. Such bison as exist to-day in America and Canada owe their lives to sanctuaries in private keeping. An allied bison was formerly abundant in Europe, but the advance of man into the unsettled spaces has limited the range of this animal, which is to be found, however, in fair numbers in the forests of the Russian province of Grodno and in the Caucasus.

America has no buffalo; Europe has, but this is an importation. It originated in the East Indies, whence it was taken to India and domesticated and introduced into Egypt, Greece, Italy and other European countries. It has been a beast of burthen in Europe for the last fourteen centuries, yet all this time it has preserved its ancient instinctive love of the mud bath, and its fondness for the rank vegetation growing in marshy situations.

The Tame Buffalo of the East and the Fierce Animal of Africa

Generally docile, it is liable to fits of rage, though, as it has never been domesticated in England, we may take it that the animal has on the whole been more sinned against than sinning. It is powerful, yields abundant milk and excellent leather, but its flesh is inferior to that of the ox.

The African buffalo is a larger animal than the Asiatic species, and has never been domesticated. Opinion is divided among hunters as to whether the charge of this buffalo or that of the lion is the more to be feared. Certainly no animal attacks with more ferocity and force, and none is more feared than the wounded buffalo, which, running off, darts aside and lies down hidden, to await the coming of its unsuspecting foe. It will charge right home after it has been dreadfully wounded.

The horse had been many ages preparing for the servitude which awaited it when flint-working man first began to add it to his living possessions. We are able, thanks to the testimony of the deposits which have been explored, to trace the history of the horse back to the Hyracotherium, which was a four-toed animal no bigger than a fox. It lived in marshy land, and fed upon succulent vegetation requiring very little mastication. But through successive epochs the horse underwent many changes. Its family is the only one in which all the toes save one have disappeared.

A Land which Once Teemed with Horses and Then Lost Them All

It is clear that the hoof of the horse, the ass, and the zebra is the one toe remaining to each foot. "Splints," which lame so many horses, are merely the recurrence of reduced bones, from which anciently were produced lesser hoofs or toes. The American continent, as has already been noted, teemed with indigenous horses, long before man had set foot on the continent; and these, although not of the same species as the ancient wild horses of Europe, closely resembled them. It is evident that there existed a land connection between the Old

World and the New until the horse had practically completed its evolution; and though Spain gave America the ancestors of her present stock of horses, it is conceivable that the horse family may have originated in America.

That is, of course, purely conjectural. It is certain, however, that the horse which early man first began to tame, though it had got itself rightly equipped as to teeth and hoofs, was very different from the beautiful creature of the present day.

How the Horse, First a Source of Food, Became Man's Servant

The wild horses of Asia, with stiff, bristling manes, with heavy head and meagre tail—this was the type of horse our early forefathers first bestrode. How far back in actual years that was is of course an impossible guess, but cave-drawings in France, whose age is said to be fifteen thousand years, represent the horse as covered with a skin dressed to answer the purpose of a saddle, and with indications of bridle or halter.

The modern horse is, then, an entirely artificial product; the mean-looking beast of the wilds of Asia—represented in our London Zoological Gardens—more nearly preserves the outline and proportions of the ancient horse which first fell under the sway of all-conquering man. The horse was first pursued for food, but the time would come when a foal would be spared and would grow up as a pet of the domestic circle. Probably the idea of turning the animal to service would come to man as naturally as the idea of the capture and reducing to bondage of a less powerful species comes to the slave-making ants.

Who this original tamer of the horse was is not known. The East did not yield the horse its first home with man, for, so far as can be traced, the animal was not domesticated in Egypt until about 1800 B.C.

The First Horsebreakers and the Way They Used Their Steeds

The latest evidence points to Palæolithic man of Western Europe as the author of the conquest. Its advent in Syria was a good deal earlier than its Egyptian days, though not nearly so early as its domestication in Europe.

The ancient Britons, as every child knows, were accomplished horsemen, and had the prettty scheme in war of driving horse-drawn chariots into the ranks of an enemy, the wheels of their chariots being armed with scythes. It took many centuries to effect an improvement in our stock of horses, and the project called forth several curious Royal edicts. Some encouraged the importation of foreign horses, some forbade the export of horses, and Queen Elizabeth made it an offence to sell one of these animals to "any Scottishman."

The ass, a much-maligned animal, an intelligent creature, though possessing decided views of its own, is another ancient servant of man. To the joy of the zoologist the living representative of the ancestor of the domestic donkey has been discovered within recent years in a wild ass of Somaliland. This ass differs in no important particular from that with which we are all familiar. The donkey was first broken to service in Syria and Arabia, and taken thence to Egypt. As animals for riding, asses have played an important part in the civilisation of Moslem East Africa and of Egypt, and, it is thought, of Europe, too, in the Middle Ages. Mules are believed to have come into existence in Asia Minor in 1500 B.C., and were made common in Europe as the result of experience of their value gained by the Crusaders in the East.

Shall We See an Era in which Animals will Again Furnish Motive Power?

The mule is still of importance to the British Empire in hilly countries. Those of us who remember the days when mules supplied the motive power on certain London tramways cannot but contrast that time with the present, when the sight of a mule occasions almost as much surprise as a motor-car did a dozen years or so ago.

Fashions change in the relations between man and the animal world. Breeds of dogs become extinct, and have to be re-created by a skilful building up of characteristics blended from other breeds. Fashion brings strange things to pass in the shape and colour of cattle and cats, in horses and pigs. But the most striking change of all is that through which we are now passing, when machinery is driving animal traction from the city streets. One cannot but wonder if there is anything in the prophecy that some day we shall be driven, by the exhaustion of fuel supplies, back to animal labour, and that the horse and ass will come again to their own. For that "own," be it remembered, is only a mild slavery, imposed by thousands and thousands of years' training. Without the imposition of the terms upon which our domesticated animals have lived there could have been no talk of the pre-eminence of machinery. For, lacking animals, we could have had no civilisation out of which to evolve our schemes for a world on wheels.

A DISCOVERER WHO MARKED AN EPOCH

William Harvey, whose discovery of the circulatory system of the blood was published in 1628, was tutor to the children of Charles I., with whom he has been here depicted by Mr. W. F. Yeames, R.A.

OUR IRRIGATION SYSTEM

How the Heart Sprays the Tissues Near and Far with Food-Carrying Blood and Removes Their Drainage

THE CIRCULATION OF THE BLOOD

We have studied the body of man as a whole, and found it to be made for movement and purpose. We further found that its most evident features, and the greater part of its bulk, are composed of the bony framework, with its joints and the muscles to act upon them, whereby movement and purpose are effected. These motor structures are subordinate to the nervous system, muscles being simply the end organs of motor nerves. But before we reach the nervous system and its powers and duties, which involve the whole of the rest of man, and which will engage us to the end, we must devote a few chapters to the remarkable combination of devices whereby the body is kept alive and the nervous system and the muscles are supplied with energy for their purposes.

The circulation, and the fluid which circulates, the digestive system which replenishes it, the lungs which ventilate it, and the many glands whose products afford essential help to the process—these are the complex systems whereby the body is sustained and maintained, including the nervous system, for the purposes of the life which—or should we say "the life who"?—inhabits it.

The circulation of the blood can only be understood by study of the anatomy of the heart and blood-vessels. As the diagram shows, the body is found to contain a closed system of tubes, arranged in an orderly fashion. At no point whatever in this system of tubes, which, in the aggregate, must run to hundreds of miles, do we find a single hole, gap, or aperture. The fluid with which the system is filled must therefore move about within the system, and the arrangements for moving it must exist for that purpose. This would appear to be a meaningless proceeding did we not have evidence that certain portions of this system of tubing are neither air-tight nor water-tight, so that gases and fluids leak through them in both directions. It is for this leakage, as we shall see, that the whole system exists.

The centre of this system consists of the heart, which lies in the chest, between the two lungs, and above the great sheet of muscle called the diaphragm. Though the heart is conspicuous, large, and unique, yet it may be looked upon as simply an expanded and thickened portion of the system of tubing. In the development of the individual that is indeed precisely what the heart is, and thus indicates its origin. But it is peculiar not only in that the channel within the tubes is so much expanded in the heart, and the tube-walls so extraordinarily thickened, but also in the fact that the system of tubes is double, and that both its parts meet in the heart. If we substitute for the network of tubes found in the body a single tube, we find that it will consist of two circles, which meet in the heart, the smaller one, running from the heart to the lungs and thence back to the heart; and the other, the larger, running from the heart to the body in general and thence back to the heart.

Such, in outline, is the anatomy of the system. Add that the heart is palpably a pump, forcing the fluid within it along the system of tubes in one direction or another, and plainly it becomes a matter of the first importance to find out exactly how the fluid runs. Until we know this we cannot hope to understand why the pump, the tubes, or the fluid exists at all. It might be, for instance, that the fluid oscillates in the tubes, passing to and fro through the heart in accordance with its beats. This was the accepted idea for many ages, and is expressed by Shakespeare when he writes, "as dear to me as are the ruddy drops that visit this sad heart." As to the uses of this

process no conjecture could be worth much; and the case was made no better by the fact that many of the tubes, and part of the heart itself, were supposed to contain only air, or "vital spirits," though the fact is that, throughout the whole of life, the heart and the tubes are always wholly filled with blood.

Michael Servetus, a great Spanish physician who was burnt by John Calvin, discovered that, in part at any rate, the blood does not oscillate through the heart, but circulates, travelling to and through the lungs from the heart, and then back to it. He published his discovery in a book which appeared in 1553. This was the discovery of what is now called the lesser or pulmonary circulation, from *pulmo*, the Latin for lung.

The Englishman who Made the Greatest Discovery in Physiology

In the first quarter of the next century William Harvey discovered the whole of the truth, which included the greater or systemic circulation of the blood, from the heart through the body generally (including vessels to the heart-walls and to the air-tubes of the lungs, for their nourishment), and thence back to the heart again. Part of the meaning of this discovery of the circulation of the blood, the greatest in the history of physiology, begins to suggest itself when we find that the blood returning to the heart from the lungs is sent, not to the lungs again, but to the body, while the blood returning to the heart from the body is sent to the lungs. We see now why the heart is placed on both circuits, and we learn that essentially there is only one circulation, round and round through the body and the lungs, but for the needs of pumping this is divided into two, with the pump at the junction of both.

This is an epoch-making revelation, before which no right conceptions of the working of the body and the duties of its parts were possible—so much so that the brain was thought to exist in order to cool the heated vapours rising from the heart, but after which all modern knowledge of physiology became possible.

The Four Chambers of the Heart and Their Work

The heart is a hollow muscular pump, consisting in man of four chambers—in such a creature as the frog there are only three—two smaller and thinner-walled, which form the base of the heart, and two much larger and much thicker-walled, which narrow down to that "apex" of the heart which we often feel beating against our ribs. The real division of the heart is, however, not into these two pairs of chambers, above and below, but into a right half and a left half, each consisting of one thin-walled chamber, or auricle, and one thick-walled chamber, or ventricle. We often speak, indeed, of the "left heart" and the "right heart," as both the anatomy of the heart, the history of its development, and the functions of its two "halves" entitle us to do. It *is* the fusion of two hearts, and there is no passage of blood from one to the other in a properly formed heart, either by any channel or by leakage. It is absolutely essential for the whole purpose of the circulation that this should be so. Nevertheless, for bodily convenience the two hearts are fused as one; and in the matter of the pumping we find that normally the two auricles always beat together, then the two ventricles, then a rest, then the auricles again, and so forth, so that each of us illustrates the ideal of "two hearts that beat as one."

The left heart receives into its auricle the blood from the lungs. The beat of the auricle pumps the blood into the ventricle. When the ventricle beats, as it does the instant that the blood from the auricle has entered in sufficient quantity to stretch and stimulate it, the blood is prevented from returning to the auricle by the closure of a valve with two flaps, which, owing to its resemblance to a bishop's mitre, is called the mitral valve.

How Blood is Driven from the Heart All Over the Human Body

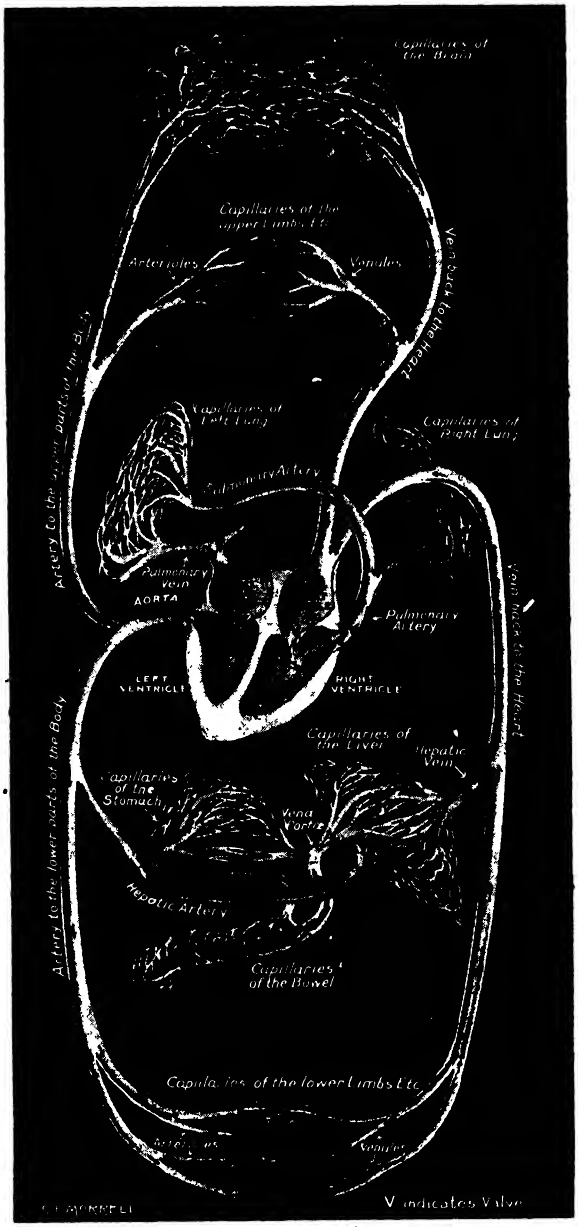
The blood has thus no choice but to rush into a large vessel, called the aorta, which springs from the left ventricle, and carries the blood, by means of its branches, to every part of the body, from scalp to sole, its first branches being given off to the muscular substance of the heart itself, else none others would be of any use.

The right heart receives into its auricle the blood from the body, including that from the walls of the heart. The beat of the right auricle, simultaneously with that of the left, pumps its blood into the right ventricle. When the right ventricle beats, the blood is prevented from returning to the auricle by the closure of a valve with three flaps, or cusps, which is therefore known as the tricuspid valve.

The blood has thus no choice but to rush into a large vessel called the pulmonary artery, which springs from the right ventricle, and carries the blood by means of its branches to the two lungs. The circulation

of a red corpuscle, say, would thus run as follows: Left auricle, left ventricle, aorta to heart-wall, brain, toe, or what not, as chance might direct, back to right auricle, right ventricle, pulmonary artery, right or left lung, as chance might direct, and thence back to left auricle again—the whole process taking, on the average, probably somewhat less than a minute.

We should add that at the beginning of the aorta and the pulmonary artery there are strong valves, so that when the ventricles relax after driving their blood into these vessels, it cannot return, any more than it could return to the auricles when the ventricles beat. These four valves of the heart are thus of vast importance; and what we call—or rather what we *should* call—heart disease, is almost always a defect of one or other of these valves, either so that it cannot close properly, or so that it is contracted and interferes with the onward flow of the blood. The almost universal use of the term "heart disease" to mean merely any defect in the vigour of the heart-beat is an abuse of the term, and causes untold distress to large numbers of people, who confound, say, the palpitation of an unexercised heart, or a nervous heart, with the distress of a heart suffering from valvular disease, which is always entirely incurable, which usually threatens life, and which is relatively very rare.



A PICTURE DIAGRAM OF THE CIRCULATORY SYSTEM

If we examine any chamber of the heart, we find that it consists of three layers, namely, an external coat, a muscular wall, and a perfectly smooth inner lining, which covers the valve-flaps and is such that in health it offers no irritation to the blood, and does not induce it to clot. The outer coat is notable, for the whole heart is practically enclosed by, not *in*, a closed and empty and collapsed smooth bag which is folded around the heart, so that at every beat one part of the smooth surface of this bag plays against the other. The arrangement is in principle similar to that found in the smooth lining of a joint, and still closer parallels are found in the case of the lungs and the bowel. In all these cases the moving organ—bone, heart, bowel, lung—has a closed smooth-lined bag wrapped around it, so that the surfaces which actually move against each other are furnished by the opposite sides, or insides, of the closed bag. In the case of a joint the bag is called the synovial membrane, the great bag in the abdomen is called the peritoneum, the two bags for the two lungs are called the pleuræ, and the bag which envelops the heart is called the pericardium. In any of these cases inflammation naturally produces some fluid inside the bag,

which may amount to ounces instead of just a drop or two. Pericarditis, as inflammation of the pericardium is called, naturally embarrasses the movements of the heart, and is one of the important complications of rheumatic fever.

The muscular coat of the heart has been already described as being the most important illustration of muscular tissue in the body. It is thin in the auricles, whose work is light, thick in the right ventricle, which has much heavier work, and very thick indeed in the left ventricle, whose work is much the heaviest of all. The natural principle of economy is thus illustrated, and further so by the results of valvular obstruction, or of persistent contraction and tightness of the arteries in the lungs or in the body generally, as also by the results of hard exercise, or the opposite results of lack of exercise. In all these and similar cases the portion of the heart-muscle which is either called upon to do more work or is relieved of work, shows overgrowth or hypertrophy in the one case, and flabby atrophy on the other.

The degree of hypertrophy is, of course, limited by the inherent capacity of the portion of muscular tissue in question; and the maintenance of the hypertrophied muscle, in cases of heart disease, over-exercise as in professional athletes, and so forth, depends upon the blood-supply that reaches the walls of the heart through the first two branches of the aorta, the coronary arteries, from *corona*, the Latin for crown, so called because they form a kind of crown round the heart. The size of these most vital arteries is limited; and the time too often comes when an overstrained heart with hypertrophied walls becomes unequal to its task because the walls undergo fatty degeneration, the muscle fibres being replaced by almost lifeless fat, which cannot contract. The sequence of events in these very common cases cannot be understood except by study of the anatomy of the heart, including its own blood-supply.

The inner coat of the heart-wall is very complicated, partly because of the wonderful mitral and tricuspid valves, and partly because the muscular coat projects inwards in various ways and places, sometimes forming parallel strands like a comb, and in other cases forming round knobs of muscle to which are attached strong fibres that run to the edges of the valve-flaps, and help to close them properly. But at every point, whether on muscular projections, valve-flaps, or strands of fibrous tissue, the blood finds itself in contact with the exquisitely smooth lining of the heart, which is called the endocardium. This lining has enemies, pre-eminently the poisons produced by certain microbes, of which those causing rheumatic fever are chief. Inflammation of the edges of the valves, which have to stand so much strain, involves their roughening, and then the blood is bound to clot upon the roughened surfaces in order to help them to heal and recover. This they commonly do, at the cost of some distortion, so that the valves thereafter are either constricted or permit some return of the blood through them.

Rheumatic fever is most apt thus to injure the valves of the left side of the heart, especially the mitral valve, since the pressure and strain are always greatest on this side. But, before birth, the strain is greatest upon the right side of the heart, which must pump the impure blood to the placenta, or "after-birth," where its propinquity to the maternal blood will purify and nourish it. Thus, if the expectant mother be attacked by rheumatic fever, and the poisons reach her child, it will be apt to be born with valvular defect on the right side of the heart, to match the damage done to the left side of the mother's. These events are not very common, but they illustrate many notable truths of the circulation.

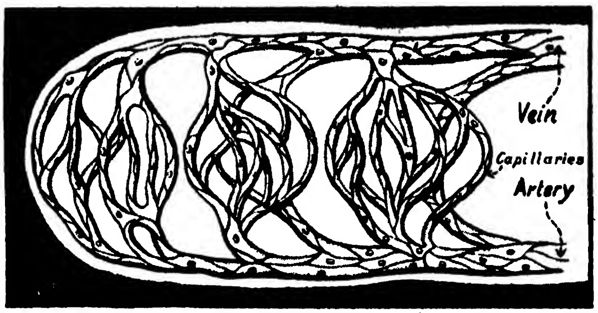


DIAGRAM SHOWING THE PRINCIPLE ON WHICH BLOOD FLOWS THROUGH A FINGER

The aorta, the pulmonary artery, and all their branches are similar in essential structure to the heart itself. Their muscular coat can and does contract, but this contraction is not rhythmical, and does not forward the flow of blood. In some creatures, of lower type, the blood-vessels may be contractile, like the heart, but in ourselves that function of beating has been exclusively taken over by that portion of the system of tubes which developed into the heart itself. After death the arteries

are found empty of blood, and hence their name of arteries—or "air-teries"—which means air-carriers. It was the great physician Galen who, many centuries after the Greek name had been given to them, found that arteries are misnamed, by opening an artery in a living animal, and observing that it contained blood.

When an artery is opened, by any means, the blood spurts rhythmically from it. That is the natural consequence of the pulse which is characteristic of all arteries, and which distinguishes them from the other kinds of blood-vessels. This pulse is produced by the heart, and in no degree at all by the contraction of the muscular coat of the arteries themselves. Arteries are elastic, and the jet of blood forced from the heart when the ventricles contract distends them. Then they resume their former size by virtue of their elastic rebound. The muscular coat is very important in connection with the pulse, but as regards any given pulsation its function is entirely that of a passive elastic coat.

Once we have excluded the muscular coat of the arteries from any rhythmic contraction, we can refer the pulse, in its origin and its rate and its rhythm, entirely to the heart-beat. The actual size of the artery we feel, and the extent to which its calibre varies during the pulse, depend largely upon the extent to which its own muscular wall is in a state of steady contraction. Thus the pulse tells us something, if we are skilful enough, about the artery itself, which we could never learn from the heart; but the greater part of what it tells, and all that any but a few experts can learn with certainty, is information about the beating of the heart, and it is that information, chiefly or wholly, which the doctor seeks when he feels the pulse.

Obviously, there must be a pulse in all arteries, and for the same cause, and the pulse in all must be almost simultaneous, though of course the wave of blood will take longer to reach an artery on the back of the foot than the familiar artery in front of the wrist which we usually call the pulse. But if we feel both wrists we can notice that the pulse reaches them simultaneously, and inappreciably later than the beat of the heart—or, rather, that portion of the heart-beat which we notice, and which is due to the ventricles. The presence of this pulse is the characteristic of the arteries, and it accounts for the considerable strength and thickness of their walls, which contrast even more markedly with the walls of veins than the ventricles with the auricles of the heart. If we trace any artery onwards, we find that it divides and gives off branches, until at last we reach, or the blood reaches, a multitude of very small arteries, which are therefore called arterioles. The pulse-wave reaches the arterioles, but it gets no further. Small, numerous, and strong, they disseminate and smooth out the pulse-wave so that the flow of the blood beyond them, until it returns to the heart, is continuous and even. Probably this is the most important function of the arterioles, for we may suppose that a smooth and steady stream is essential in the next stage of the circulation.

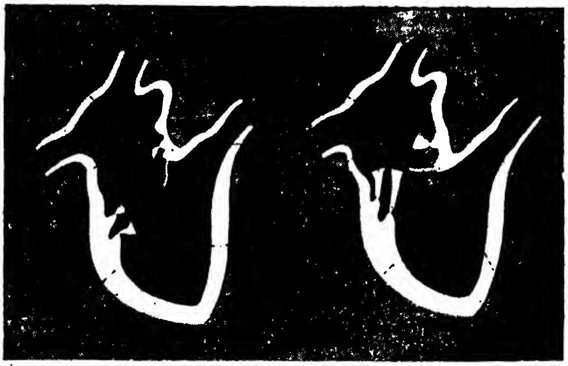


DIAGRAM SHOWING HOW THE MUSCLES WORK THE LEFT HEART

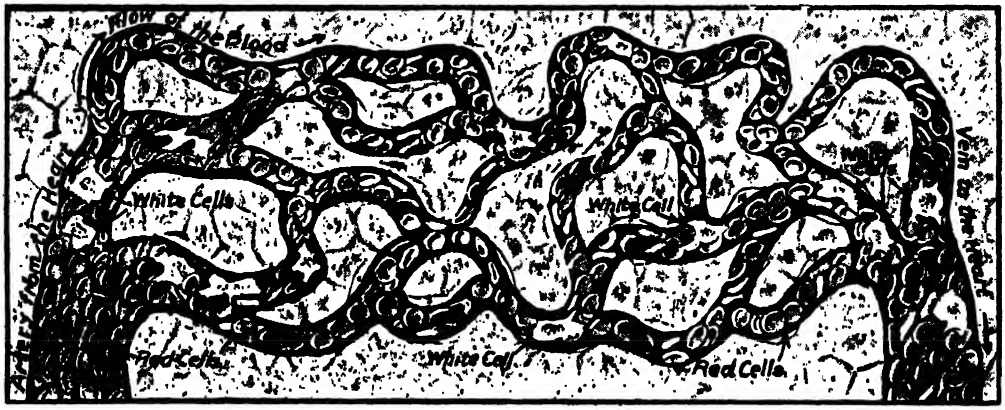
This next stage is through a countless number of very tiny and thin-walled blood-vessels, which, being hair-like, are called capillaries. These have no fibrous outer coat and no muscular coat, but consist of no more than a single layer of smooth, flat cells—as if an artery had been divested of everything but its lining. Such thin walls could not withstand a violent pulse, nor anything like the remarkable pressure of the blood-stream, even between the heart-beats, as it can be measured in one of the arteries. But the pressure has now been so diffused and equalised that the capillaries can stand it, while the stream has become proportionately sluggish—a great contrast to that which carries the blood from heart to wrist in a fraction of a second.

The capillaries unite in time, after forming a fine, hair-like network in whatever part of the body we may be examining, and form tiny veins, which compare with the smallest arteries or arterioles, and are called venules. Thence the blood returns to the heart—from the lungs or the body in general as

the case may be. The capillaries are, of course, essential to the completion of the circulation. They were never seen by the illustrious discoverer of the circulation. Harvey was compelled to assert what was evidently the truth—that somehow the blood reached the veins after leaving the arteries, and so returned to the heart, but he was denied the crowning satisfaction of being able to see for himself the actual continuity of arteries and veins by means of the capillaries. That discovery was made in 1661, four years after Harvey's death, by the fortunate Italian anatomist Marcello Malpighi, who was the first to explore the body with the microscope, as his compatriot Galileo was the first to explore the heavens with the telescope. These capillaries can readily be seen by a very feeble microscope in such places as the web of the frog's foot; and higher powers show the stream of blood passing through them, the red cells all jostling one another to get past. Nowadays the process can be submitted to continuous photography; and thousands of people nightly have witnessed in our day, on the screen of a bioscope, the sight for which the discoverer of the circulation might gladly have given ten years of his life.

From Harvey's or Malpighi's point of view, and from our first point of view to-day, the importance of the capillaries lies simply in the fact that they exist and make the circulation possible. The blood is not discharged by the arterioles into the tissues, and then sucked up by the veins. Blood could not stand such a process, and the smallest drop of it undergoes most serious changes if it escapes from the circulatory system.

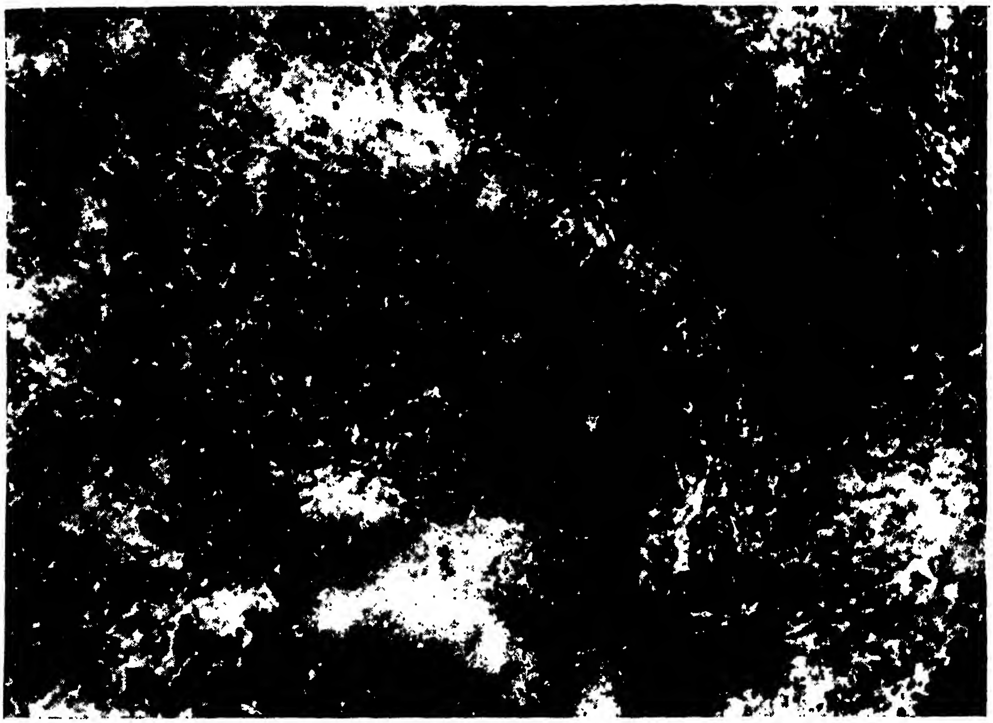
But we have a second point of view to-day and we learn that not merely do the capillaries make the circulation possible, but it is for the capillaries that the circulation exists at all. Though not one drop of blood should ever escape from the blood-vessels as a whole, yet the circulation and all its structures are useless unless, at some point, the system leaks; and it is through the capillaries alone that, in both directions, this leakage occurs. Every part of the body that is to live must therefore be supplied with a network of capillaries—brain, muscles, roots of hairs, or anything else, except the transparent front of the eye, which must remain transparent, and is thus served by the capillaries which normally crowd against but never transgress its margin. For these tiny invisible vessels the whole machinery exists. We begin to understand, now, why the stream through them must be equal and slow.



PICTORIAL DIAGRAM SHOWING HOW THE BLOOD PASSES THROUGH THE CAPILLARIES
The capillaries are really very minute, some 2000 to the square inch. In this drawing the capillaries and the red and white cells of the blood have been greatly magnified for the purpose of showing clearly what happens in the circulation of the blood.

As capillaries have no muscle in their walls, and their resistance is of the feeblest, they are passive recipients of whatever quantity of blood reaches them. They can dilate considerably, and retain wonderful powers of growth and development, so that, if occasion arises, the richness of the capillary network in any part can be vastly increased. The supply of blood to the capillaries is entirely dependent upon the state of the arterioles, which are thus the sluice-gates of the circulation. The muscular coat of the arterioles is under nervous control, so that, in the last resort, the nervous system determines from moment to moment, day and night unceasingly, the exact amount of blood that passes through the capillaries of any part of the body.

Thus the sluice-gates in the wall of the stomach flood it with blood after a meal, those in the cheek flood it when we blush, those in the brain flood it when we read or write or reckon—as has been proved by simple experiment—and those in any part of the body that is in danger, attacked by microbes, or mechanically damaged, are opened to flood it with the blood which alone can save. Again, in exposure to cold, the sluice-gates in the skin and all external parts of the body are shut down so tightly that a very minimum of blood can pass into the capillaries. This naturally makes us feel cold and shiver, for the nerves of cold in our skin are disturbed, but it saves our lives by concentrating the warm blood in the vital organs within, so that they shall not be frozen to death.



THE VESSELS OF BLOOD IN THE TAIL OF A TADPOLE

This picture was taken by putting the tail of a tadpole under the microscope. Inside the tiny blood-vessels can be seen the oval red blood-cells of the animal. On each side of the blood-vessels can be seen epidermic cells, the large black spots being pigment cells. This photograph is from a cinematograph film made by Messrs. Pathé Frères, the whole film showing the blood in actual circulation.

This local control of the blood-supply is so essential a matter that it needs every possible contrivance. It has even been found that not only are the walls of all arteries and arterioles supplied with motor-nerves, but they also have a separate supply of nerves which, when they order, order the relaxation of whatever contraction or tone the muscle fibres possess at the time. It is as if merely to order or not to order were insufficient for so delicate a task; it is necessary also to *order not.* Thus we speak of a system of vaso-motor or vaso-constrictor nerves, and a system of vaso-inhibitory or vaso-dilator nerves, which control the size of the blood-vessels—or, rather, of the arteries—and thus, by varying pressure within them, of the capillaries.

For each of these two systems of nerves, running to every artery and arteriole in the body, in brain, or scalp, or toes, there exists a minute "centre" or collection of governing nerve-cells, in the lowest and oldest portion of the brain, called the bulb. Close beside one another inside this small portion of the brain, which is only so large in all as the last segment of one's thumb, lie the vaso-motor and vaso-inhibitory nerve-centres, so placed as to respond to every imaginable influence borne to them by nerves from an ingrowing toe-nail, or from those brain-areas concerned in a thought of shame or fear; and thereafter the toe, the cheek, or what not, blushes or turns pale, according to the order given.

This process is notoriously outside our own control, as it well should be, considering its complexity and importance, day and

night. We know and care nothing of it, but without its continuous supervision of the circulation of the blood, in every organ and tissue of the body, we could not live for an hour.

From the capillaries, as they reunite, proceed venules, we said, which unite to form veins, and thence to the heart—to the left auricle, if we be looking at the pulmonary veins; to the right auricle, if we be looking at any other—including the bronchial veins, which return the blood that has been nourishing the air-tubes of the lungs. Venules and veins are similar in structure to arterioles and arteries, but are very much thinner and weaker-walled. They are capable of some little contraction or relaxation, and should certainly show some "tone" if their health is to be maintained, but they are essentially passive and mechanical in function. There need be no valves in arteries or capillaries, but in the walls of the larger veins we find occasional valves so placed, as has been noted elsewhere, that they interfere with the backward flow of the blood, but would appear to have been designed more to suit the needs of a four-footed than of an erect animal such as the body of man.

The Pulse which Indicates the Rate at which the Heart is Beating

The health of the veins and their valves is thus a matter of importance in the case of the lower limbs, as also in some other parts of the body, where they are liable to become enlarged and relaxed or "varicose."

Thus by the veins we return to the heart, the sole motor of the circulation. It is time to study its action. We find, by feeling the pulse, or placing a hand on the chest, where we can feel the "apex-beat" of the heart, that it beats about seventy-five or so times every minute in an adult man, perhaps eighty times a minute in the adult woman, and oftener in children, the pulse of the new-born infant being nearly twice as rapid as that of the adult. Old age and idiosyncrasy, as well as sex, affect the rate of the pulse. Some hearts are normally very infrequent in their beat, such as that of the first Napoleon, which is said to have normally beaten only forty times a minute. Posture is important. When we stand, or even when we sit upright, the pulse is several beats faster per minute than when we lie down, since in the upright posture more beats will evidently be required for the nourishment and aeration of the brain. Thus to lie down and, still more, to sleep, is to rest the heart.

We are unconscious of the normal beat, but when the heart beats abnormally from any cause we become aware of its thumping against the chest-wall, and this consciousness of the beating of the heart is called palpitation. To anyone who has watched the movements of the heart by means of the Röntgen rays, and who knows the mighty and sudden force of the beat, the extraordinary fact is that we should commonly be unaware of this tremendous convulsion which occurs just behind the chest-wall oftener than once in every second of our lives.

The Little-Known Fact that Palpitation is Not a Disease of the Heart

It is to be noted that palpitation is almost invariably of external origin, nervous or digestive, and very rarely indeed is any indication of real disease within the heart. The eye occasionally falls on advertisements which suggest otherwise; and, indeed, many people suffer, and give themselves palpitation, by being unnecessarily afraid of it.

It is well known that the heart of the dead frog or of many other animals can be removed and will beat for hours if it be properly supplied with fluid to beat upon, and, especially in the case of the mammalian heart, if it be supplied with a warm fluid containing certain salts and sugar, the great heart-food. We thus conclude that in all these cases the beat of the heart arises within itself. That is also the case with the heart of man. It contains important groups, or ganglia, of nerve-cells, whose fibres run through the substance of the heart. The details of the nervous apparatus have only recently been observed by a young Japanese student, though millions of hearts have been dissected for ages past, and though the nervous machinery is quite evident to the naked eye when looked for in the right way.

The Wonderful Mechanism by which Blood is Pumped Through the Body

The order of events is precise, and constitutes what is called the cardiac cycle. The auricles are first ordered to beat by the intrinsic nerve-cells of the heart. The beat of the ventricles follows instantly. There is then a relatively long pause, completing the cycle, before the auricles initiate it again. The pause is a vital matter for the unsleeping heart. Its alternation of work and rest (including meals) is the most rapid imaginable, and suffices it for a lifetime. It is during the pause after the relaxation of the ventricles that the blood just sent through the coronary arteries can travel through the substance of the heart, and between its

relaxed muscle-fibres. This process alone supplies the heart muscle with food and oxygen, and drains it of its poisons; and it is only possible during the pause.

If we listen to the heart—an easy matter—we hear two loud sounds, which follow a certain rhythm corresponding to the cardiac cycle. The first sound is produced when the ventricles beat, and is caused by the vibration of the tightly closed and stretched valves that prevent the return of the blood to the auricles. The second sound, more musical and much higher in pitch, occurs when the ventricles relax—that is, at the beginning of the pause. It is due to the vibration of the valves at the root of the aorta and pulmonary artery, which are made to sound by the great pressure of the column of blood above them, trying to return to the dilating ventricles. These sounds should be clear. If we hear murmurs accompanying or replacing them, we may be able to know that, for instance, the mitral valve is incompetent, and allows a soft swish to mingle with, and partly replace, the first sound, as a little blood leaks back into the left auricle.

The Instruments by which the Heart Can Be Seen and Heard at the Same Time

The study of the invisible heart by means of the stethoscope, applied at various points over it, and conveying sounds and murmurs which enable us to define the health or illness of the organ underneath, is extraordinarily interesting and useful. To-day, it has taken a new phase, for the Röntgen rays can be employed together with the stethoscope, and the heart can be simultaneously seen and heard to beat. Much improvement in the treatment of ill hearts and in the care of young, growing hearts is now following upon our better knowledge of this subject.

It is a capital fact that the beat of the heart arises within itself, and not in response to rhythmical orders from without. The fact would not have been of so recent determination were it not that the problem of deciding it is complicated by the passage to the heart from the brain of two pairs of important and potent nerves. We have already seen that the capillaries throughout the body can be flooded or emptied by means of nervous control of the arterioles, and that this control is sensitive to every incident in the body. Just so must the heart itself be capable of control by the brain, sensitive to all manner of disturbances, physical and psychical, in this case as in the other. Thus we find that the bulb of the brain also contains a pair of tiny "centres," groups of nerve-cells, whence run fibres to the heart, such that, when the cells order, the heart beats faster and more powerfully. But the bulb also contains another pair of "centres," whence run nerve-fibres such that, when this governing cell gives orders, the heart beats more slowly and feebly. The parallel with the nervous control of the arteries is thus exact, except that the question of rhythm does not come into their case.

How the Heart is Controlled by Nerves from the Brain

The nervous machinery is even more complicated and subtle than these facts express. We find that the cardio-motor nerves, unlike the vaso-motor nerves, are usually not in action. They act to spur the heart, and to expedite the rhythm of the beat, which its own nerve-cells are apparently determining, only when there is special occasion. But the pair of cardio-inhibitory nerves are always in action. The heart runs in a pair of tightly held reins; and if those reins be relaxed by fear, or poisoned by such drugs as belladonna and its allies, or if they be divided, the heart promptly races, and beats at twice its normal speed. Thus, though the beat of the heart arises in its own nerve-cells, the rate is not of their choosing. The rate they would set is double that which is actually maintained, so tightly are the reins held in the strong hands of the cardio-inhibitory centre.

The value of this extraordinary arrangement is evident. On the slightest occasion, and instantly, at a word, a thought, a pin-prick, the reins can be relaxed and the heart will begin to fly. In other circumstances the cardio-inhibitory nerves may increase their action, and the cardio-motor nerves may act as well, so that the heart beats in a slow rhythm of mighty thumps.

The Balance that is Maintained in the Circulatory System of Man

We may add that the four great groups of nerve-cells which govern the circulation, the centres for cardiac stimulation and inhibition, and for the stimulation and inhibition of the arteries, are in close connection and balance, so that, for instance, if the arteries contract and raise the pressure of the blood within them, the heart at once beats more powerfully, to maintain the circulation against the increased resistance.

Such are the bare essentials of the circulatory system of man. We must now consider the vastly more remarkable fluid which circulates within this system, and for the circulation of which the system exists.

THE LIGHT THAT CURES DISEASE

Light is the great enemy of the parasite Realising this fact, Niels Finsen, of Copenhagen, introduced the red-light treatment of small-pox, and went on to invent the famous Finsen lamp, which is here shown at work in the London Hospital, curing lupus and other terrible forms of skin disease.

THE ARMIES OF THE AIR

How the Worst Enemies of Health Lurk in Dirt and Darkness, but Perish in the Light of the Sun

"LET THERE BE LIGHT-LET THERE BE HEALTH"

To say in general terms, as has often been said, that life is the child of light, is more than science warrants. Life may have been conceived long before the earth's atmosphere became translucent, and there are many forms of life which flourish in darkness now. On the other hand, we know that a child or a flower requires light if it is to flourish. Obviously, therefore, we must distinguish; and we may prepare ourselves for what is to follow by saying that, in general, light is the enemy of low forms of life, and the friend of higher forms partly by direct action upon those higher forms, and partly because the enemy of their lowly enemies is their friend.

If, when we speak of light, we were naming anything simple, our problem would be simple. But light is exceedingly complicated. Sunlight has many parts, varieties, constituents, whose properties vary, and visible sunlight is only a part of the whole radiation of the sun that traverses the atmosphere. Visible light is thus invariably accompanied by invisible radiations, "the same but different," which may and do have notable effects upon us, and upon our surroundings, living and lifeless. These invisible radiations are partly heat-waves and partly waves called ultra-violet, because when the sun's radiation is spread out by a prism, so as to form a band of colour, these rays lie beyond the violet end of that band.

Each of these invisible radiations has its own effect, and each behaves differently in regard to such substances as glass. Thus, the heat-rays may be responsible for "heat-stroke," and may play a chief part in what we call "sunstroke." They readily pass through glass, behind which we spend so much of our lives in these days. On the other hand, ultra-violet rays have a very powerful and characteristic chemical property of their own, as the evidence of photography shows; and they are largely arrested by glass. This chemical property is definitely antiseptic, among other things, and can readily be proved to kill microbes, with results most important for health. On the other hand, it has marked effects upon the skin, which may be deleterious. It appears to be the chemical action of these rays that is chiefly responsible for sunburn, freckles, and more general pigmentation of the skin. Here, again, we can be dogmatic only at the expense of science, for we can scarcely say whether the tanning of the skin is not protective and beneficial; and there are distinguished authorities who attribute to this cause the darker skin colour of those men, and, in general, of those animals, who live nearest to the tropics. Lastly, it appears that the red constituents of sunlight are the hottest, and resemble the invisible heat-rays in their action, while the blue and violet rays are cooler, and resemble the ultra-violet in their action, as we should expect.

Let us further remember that light and other radiations exert a mechanical pressure upon every object they strike, and that all these radiations are essentially electrical or electro-magnetic in character. We shall realise that we are dealing with a large and obscure subject, as no one knows better than we who study its literature and find how inadequate it is. The fact is that the real knowledge of light and radiation in themselves is quite modern, and that the scientific hygiene of the subject has had to wait for the development of its physics. Nevertheless, some positive knowledge exists, and parts of it are vital. On the other hand, there is a good deal of rubbish or misinterpretation, which may first be disposed of.

We frequently hear accounts of scientific experiments made in America and

elsewhere for the cure of disease by special forms of light. Thus we learn that mania and other kinds of insanity, and also insomnia, have been relieved by the application of blue light or green light, the patients' excitement being soothed. This action is reasonably contrasted with the converse property of red light, which stimulates and produces motion, in the traditional case of the bull probably not baseless. We are also told, frequently, that the application of blue light will induce anæsthesia for surgical purposes, so that grave and otherwise painful operations may be performed, perhaps even in cases where the administration of an anæsthetic would have been too dangerous to be permissible.

The Great Variety of Modern Popular Forms of Light-Baths

The question is as to the truth of these statements, and their explanation if they be true; for obviously they offer very great possibilities in the cure and relief of disease, such as should not be confined to America. Similarly, we must inquire into the various forms of light-cure which are recommended for rheumatism and gout, for muscular pains and weakness, for sciatica, and so forth. People who have the means can now expose themselves, or any portion of themselves, either here or on the Continent, to all manner of light— to sun-baths, or electric-light baths, in which one may sit, or to which one may expose a stiff limb, or what not. The light may be of any colour or intensity. It may be filtered through glass, so as to intercept certain rays, or through quartz, so as to intercept other rays. Yet, again, we may be treated by means of "radiant heat" baths, in which case the same question is really involved, though the particular radiations employed are below the red end of the spectrum of visible light, and thus cannot be seen. This is, however, most emphatically a light that can be felt.

The Commercial Employment of Radiations to be Regarded with Discretion

All this huge modern development, daily increasing, has a commercial side. Owners of establishments, doctors, electricians, makers of apparatus and so forth, are all interested; and, as in every other case, the commercial complication, though inevitable, natural, and indeed essential for development, complicates the scientific truth. The impartial critic finds it hard to know what to believe. It is easy enough, if one takes the sceptical line of believing nothing, but, in the face of many positive and well-attested facts, that is out of the question. In due course we shall look at two instances, at any rate, where the medical employment of radiations of one sort or another daily produces absolute cures of real illnesses, that even threaten death, and may quite fail to yield to any other remedy. These instances definitely exclude a superior scepticism, lest we may deny something just as invaluable, but less familiar.

We are to dismiss the stories of the relief of mania, the production of sleep, relief of pain, and induction of anæsthesia by blue light, and so forth. There is no doubt that such results may occur, in America or anywhere else where people are suggestible, and that is everywhere. But the action is essentially "hypnotic," or, in the more scientific language of to-day, it depends upon the power of suggestion. This is not to say that colour matters nothing for health of mind and body, and notably of the eyes. On the contrary, we do well to remember that the eyes have been evolved in accordance with the facts of the external world, whose dominant colours are the blue of the sky and the green of grass.

Some Conditions Under which Colour and Radiant Heat are Not Unimportant

We may thus expect that the colours most restful to the eye, because most natural to it, shall be blue and green; and wise people usually prefer these colours in, for instance bedrooms. Later we may point out, also that, in certain states of health or disease, violent wallpapers with violent designs are almost "maddening," so that the blue-light treatment of mania is at least justified to that extent.

There can be no doubt that radiant-heat baths, for instance, often relieve severe pains in joints and elsewhere. So far, so good; but the critic is quite entitled to observe that where the limb is made to perspire profusely it may be the removal of local poisons that does the good, which perspiration induced by any other means would do; and also to observe that where the heat in light causes great redness of the skin over the joint perhaps the action is not so very different from that of an embrocation or a mustard plaster. Yet we must wait for more knowledge, and especially on one ground, which has not been investigated, because, to the best of the writer's knowledge, it has not been pointed out before.

Exposure to light or other forms of radiation which are not wholly reflected—and none are wholly so—means much more

than, say, the irritation of the skin by rubbing, for light is a physical reality, a form of energy, and the energy which is not reflected actually enters the body. The patient or person thus receives a positive *dose* of something, which must produce consequences. Radiation is a mode of energy. Exposure to it means, in large measure, dosage with it. What are the consequences of the addition of this energy to what the body already contains—consequences which must be quite distinct from and additional to the mere response to a stimulus, important though that be—no one yet knows, but our ignorance must qualify our scepticism of the claims of the pioneers in this field.

When the Absence of the Stimulating Power of Light may be an Advantage

With one other observation we must leave all this uncertain ground of the action of light, and pass to what is sure. It is that, whatever be the value of blue or green light in mania and so forth, there can be no doubt as to the value of darkness, or absence of light, in many cases. Every oculist proves this every day. Every nurse and doctor knows the value of darkness, not only in cases of eye-strain or eye-disease, but in many other cases. We need sleep, and darkness promotes sleep. Life is a rhythm. We need stimulation, but we also need absence of stimulation. Physical rest, best in bed, means a minimum of stimulation by touch and pressure; silence means a minimum of stimulation by sound; and darkness a minimum of stimulation by light. These combine to promote rest, recuperation, repair, sleep, which are necessary if their opposites are to succeed.

Turn we now to the proven cases, triumphs of our own day, where light restores health and life. This is not part of the general question of man *versus* microbe, which is part of the problem of species *versus* species in the struggle for life, and must be discussed elsewhere. What we discuss here is simply the local application of certain forms of light to diseased areas of the human body, with the result of restoring health. The facts cannot be too widely known, and their interpretation is of high scientific interest.

The Inventor of the Finsen Lamp Struck Down at the Height of His Powers

First in order of time comes the Finsen treatment of lupus and kindred parasitic diseases of the skin. Lupus is a chronic form of tuberculosis of the skin, and of the mucous membrane of the nostrils, etc. It is a minute part of the general problem of tuberculosis, into which light certainly enters, but which the Finsen treatment does not solve. Granted, however, that cases of lupus occur, the Finsen lamp has its place. Other superficial diseases of the skin, due to the invasion of other microbes or even animal parasites, are also amenable to this treatment.

Niels Finsen, of Copenhagen, prematurely struck down at the height of his powers some seven or eight years ago, first drew the attention of science to himself by his introduction of the red-light treatment of small-pox. His idea was that much of the harm of small-pox is due, as it certainly is, to absorption of poisons from the pustules in the skin, to say nothing of the subsequent disfigurement that they cause. The development of the pustules, of course, depends upon chemical action; and it is the rays of light in the violet region of the spectrum that promote chemical activity. Red glass and blinds should therefore prevent this chemical activity in the patient's skin, as they prevent similar activity in the photographer's plates. It is hard to estimate the precise value of this treatment, because small-pox is so profoundly influenced by previous vaccination that the effect of any other influence can scarcely be measured.

A Triumphant Success in One of the Most Terrible Forms of Disease

But this first piece of work is memorable, because from it Finsen went on to argue that the very part of the spectrum which he excluded from cases of small-pox, on account of its chemical powers, might be invaluable in other forms of disease, where the chemical powers should have an antiseptic effect and kill the disease agent. Concentrated sunlight, transmitted and focussed by a lens of quartz, undoubtedly produces a marked effect upon the skin, even though the light be cooled. More convenient is the Finsen lamp, wherein the light is produced by an electric arc, passed down a tube, focussed by a double lens of quartz, filtered of its heat-rays by a stream of cold water which is kept running between the plates of quartz, and finally directed, in high intensity of violet and ultra-violet rays, but very low intensity of heat-rays, upon the skin. This device was introduced into this country at the suggestion of Finsen's countrywoman, Her Majesty Queen Alexandra, and found its first home here at the London Hospital.

There is no doubt whatever that the Finsen light cures lupus and some other forms of skin disease. The applications may require to be numerous, and the expense is

considerable, while each exposure may need half an hour or more. There is a good deal of painful reaction also, and cases occur which are intractable. But under the best modern conditions, and especially in early cases, the light treatment is triumphant; and nothing can compare with it for the quality of the soft, normal-looking skin which replaces the disease—a great contrast to the serious disfigurement and contraction which follow the surgeon's ordinary methods when those are successful.

How the Tissues are Charged Afresh with Energy and Enabled to Cure Themselves

But experience here shows how exceedingly superficial is the penetration of light. Even in this most intense form it goes only very little distance, being rapidly absorbed by the red matter in the blood that circulates through the skin. The fact is of double significance; first, it requires that the area of skin under treatment be much pressed upon, so as to keep the blood out of it and enable the rays to reach the deeper layers; and, second, it adds to our interest in the question already asked above—What effect does the absorption of light-energy by the body produce?

Finsen's very natural theory was that the curative effect of his light is due to its antiseptic action on the tubercle bacilli, or other microbes, which cause the disease in question; and what we now know of the action of light on tubercle bacilli would seem to justify his view. Nevertheless, the opinion of the best authorities appears to be that the light enables the tissues of the patient to cure themselves. They are "stimulated," as we say when our ideas are becoming vague. At any rate, changes occur, perhaps due to the quantity of energy which must be absorbed by tissues thus exposed, in consequence of which they are able to kill the parasites, and thereupon they heal with the minimum of loss of tissue and deformity.

The Rays that Enable the Doctor to See Foreign Obstacles Inside the Body

Not less remarkable is the curative property of the form of radiation which we call the X or Röntgen rays. These rays are of obscure nature, but they are certainly electrical, and probably belong to the same class of radiation as ordinary visible light. Certainly their effects must be here considered along with those of light in general. The Röntgen rays are best known to the public in connection with their power of penetrating many obstacles, in a fashion which may be of great value to doctors, as revealing the position of a stone, or of a swallowed or inhaled coin, or the ends of a broken bone, or the state of a dislocated joint, and so forth. But, like other forms of radiation, these have a notable influence upon the life and health of the body.

The physicists divide the kinds of X-rays, roughly, into two, which they call hard and soft, and which can now be produced separately for medical and other purposes. The hard rays are so called because of their high degree of penetration. They are thus invaluable in the internal photography of the body. But the soft rays, having less penetration, are absorbed by the skin, and produce notable consequences there. These may be of two opposite—tragically opposite—kinds.

Thus, until the danger became known, many students of these rays, and many who have applied them in the service of healing, became gradually affected with a malignant growth of the skin which is now called X-ray cancer. Here we see that the long-continued but comparatively slight irritation produced by the rays excites and vitiates the cell-life of the skin, so that it takes this excessive and deadly form. On the other hand, large dosage with the rays is deadly to cell-life; and there are certain forms of malignant disease, notably that called "rodent ulcer," which commonly yield to this treatment, and do so in a fashion far more satisfactory than the knife can attain.

The Deadly Action of Light Upon Man's Most Deadly Internal Enemies

We note, then, that the surface of the body may respond very strikingly, in various directions, to the application of this form of electric radiation, and this fact must be remembered in further study of the action of the various forms of light upon the body. Here, at any rate, is a form of radiation the action of which is either vicious or deadly—deadly to deadly growths. One of the famous brothers Hertwig, on the Continent, has lately studied the action of these rays on the development of germ-cells, and has found parallel results. The moral can only be that the action of light must be studied more closely than ever, and may prove to be of far more importance than even the "cranks" yet realise—and in far other directions.

We turn now to what is possibly the most important part of our subject—the deadly action of light upon our most deadly enemies. Here we may confine ourselves to the most deadly and important of them all, which is the tubercle bacillus, the cause of

consumption and all the other forms of tuberculosis, including lupus. The sun, we shall discover, is a lamp greater than Finsen's, and ever doing what Finsen designed his lamp to do. For whether or not the action of light upon tubercle bacilli in the tissues be antiseptic, there is no question about its action upon them anywhere else.

As this question of the conditions of life of the tubercle bacillus outside the body of any host lies at the very root of the whole problem of tuberculosis, and as the facts are known which place the disease in our power to annihilate, we must carefully note them here. Thereafter, perhaps, no reader will fail to know what the action of light is always accomplishing for his health.

The Marvellous Variety of Conditions Under which the Tubercle Bacillus can Thrive

The tubercle bacillus is a single cell, about 1-24,000th of an inch in length, a parasite by nature, and perhaps the most adaptable of living creatures, with the exception of man himself. This microbe can live in the body of man, anthropoid apes, monkeys, bovines, canines, felines, pigs, birds, reptiles, and fish. It can thrive and multiply in birds, whose blood is much hotter than ours, and in cold-blooded animals, whose temperature is far lower. Taken from a tuberculous turtle, it can thrive at freezing-point; from a tuberculous bird, at 45 degrees centigrade. And outside any living body it can thrive on almost any medium—blood serum, glycerine agar, egg, milk, potato, and bouillon.

Already the catalogue of possibilities is amazing, if not entirely unique. Short of multiplication, which it can achieve in such an astonishing variety of conditions, both in living bodies and in lifeless materials, the tubercle bacillus still has another possibility that, taken with all the others, really puts it almost in a class apart among living things.

The Persistence of the Deadliest Microbes in a Potentially Virulent State

It can deprive itself, apparently, of most, or all, of its water, which is, of course, necessary for any active life, and assume an inert "spore" form, that can survive, without multiplying, but with its latent capacity unstinted, in conditions which do not supply any nourishment whatever.

According to the latest and best authority: "It has been calculated that a tuberculous patient may throw out in the sputum over four billion bacilli every twenty-four hours. As the sputum dries, and is reduced to dust, the bacilli are widely distributed. Cornet collected 118 samples of dust from hospital wards and from the rooms of tuberculous patients, and of these samples forty were found to be virulent to susceptible animals. The dust of a room in which an infectious patient had died was found to be infective six weeks afterwards. There is thus clear evidence that air-borne dust may carry the infective agent. On the other hand, there are certain factors which limit the spread of infection from dried sputum. The virulence of tuberculous sputum is rapidly destroyed by drying, and by exposure to sunlight, the natural enemy of the tubercle bacillus. It is to be noted, however, that, if kept in the dark, dried sputum is virulent even after two months."

The drying alone does not kill the bacillus. But drying which precedes or accompanies exposure to sunlight, "*the natural enemy of the tubercle bacillus,*" is the fatal thing. And now we can understand why tuberculosis is called a "house disease," a "dwelling disease," a "disease of dirt, dust, and darkness."

Where the Enemy Finds Its Lair, and How It May be Slain

People have thought that this kind of talk is inexact and meaningless, since the discovery of the precise agent, the tubercle bacillus. They have said that, prior to this discovery, we might call tuberculosis a disease of dust and darkness, but now we must call it an infection due to the tubercle bacillus. So it is; but we have found that darkness is essential to the life of the tubercle bacillus; that dirt and dust lying in darkness is its natural lair, and that sunlight is its natural enemy. In whatever form it be, and of whatever origin, this microbe, which can flourish in such various hosts, on such various nutriment, and can even survive months of starvation, dies by the shafts of the sun. Like many another noxious thing, it can stand anything but the light of day.

Now we really know where we are, and where the danger is, and how to avert it. The best, oldest, cheapest, safest, and only natural antiseptic is light. We are to live in the light, if for no other reason, for the sufficient one that our worst enemies cannot live there. Doubtless much more knowledge is required. The *immediately* fatal agent is direct sunlight. Diffused light is antiseptic also, but not nearly so rapidly. The combination of heat and darkness is most favourable to the development of this as of most microbes; indeed, the microbes in general may be the modern representatives of early forms of life which

flourished when the surface of the earth was hot and dark—before the sun's rays could pierce the dense atmosphere.

We need more knowledge as to the nature of the light that is most effective. Apparently it is the chemical, "actinic," "photographic" rays that do this invaluable work; and, since that is so, we have to recognise that the glass of our closed windows, though it admits the light in general, very seriously excludes the antiseptic rays. The writer is not aware of any experiments comparing the effect of sunlight upon the bacilli when acting through ordinary window-glass, or in its absence, but such experiments should certainly be made, for they evidently bear directly upon an essential problem of personal and national hygiene. These should be among the first principles of architecture and of town construction, and they should personally affect our own conduct at home.

The Primal Word "Let There be Light" Still the First Word of Knowledge

"Let there be light" is the word of modern knowledge to the people who live in darkness. Dark dust is the danger. Whatever harbours or disguises or shields dust is a source of danger, and whatever introduces infected dust is a worse. The housewife's instinct, as we have already hinted, is in absolute accord with the latest and most precise findings of science. She hates dust, and she hates the dirty practice of sweeping it into corners. If we are to have dust and dirt in our houses, let it be where we can see it; let it be displayed to the utmost advantage, for then the sun may see it, too.

Cleanliness is antiseptic, we perceive—domestic as well as personal cleanliness. To open the window and admit the unqualified sunlight is to perform an act of hygiene and cleanliness. To build or permit human habitations that are dark is a crime, not only against their inhabitants, but against human life at large, for these maladies are infectious; and the consumption that persists among the well-to-do is the price they pay for neglecting the housing of the poor.

For ourselves, we are to avoid dirt and dust and darkness in our houses. We are to forswear litter and accumulation of papers or anything else, especially upon or near the floor. We are to keep our floors clean, and by means which do not raise dust that betakes itself to darkness. Nurseries and schoolrooms for our children are to be sunny, little carpeted, well deprived of dust—*not well swept.*

Above all are we to avoid dark and unsterilised dust when there are children in the crawling stage. The infant will escape, the walking child may escape, when the crawling child in its second year or so lives near the floor and infects its hands and thence its mouth. This abomination, with definite consequences in the way of tuberculosis, used daily to happen in this country upon the floors of public-houses—one sample in three of dust from the floor of which, on the average, contains living and virulent tubercle bacilli.

The Microbe Finds Its Only Chance by Lurking in the Darkness

But the Children Act, which stopped that, has not affected the dust and dirt and darkness of the dwellings of the poor, where many children are thus infected still, with the inevitable consequences which we discover, to our surprise, in later years.

We must be cleaner in our personal habits. We must not commit the uncleanly act of brushing our clothes in the rooms in which we live. We bring in microbes from outside, and their one chance of effective survival is to get into the dark. Tubercle bacilli in the street, from the sputum of a consumptive, have little chance there, for the light will soon kill them. But if a woman rescues them with her skirt—they may readily be found in the dust from the edges of skirts and petticoats—and brings them home, and goes to the nursery to kiss her darlings, she may thereby infect the room if any cover of darkness be available.

Stupid Women who Carry About the Dust of Deadly Disease

The conduct of cleanly and fastidious women in this matter is simply incomprehensible. It has been condemned again and again on the obvious grounds that a trailing skirt cannot but pick up dirt. But now that we know what dirt contains, and what are the consequences of carrying dirt away from light into darkness, there remains no excuse for the woman who trails her skirt. Whosoever conveys tubercle bacilli from light to darkness is an enemy of the people. The short skirt which came into fashion recently, perchance, should be made to remain, perforce.

The thing is not a joke, as so many people erroneously suppose. The composition of street dust is horrible, including the excreta of animals, and the expectoration from many cases of consumption, influenza, and bronchitis. In the

open air, and exposed to the light, these dangers to health are destroyed—even the resistant and adaptable tubercle bacillus, which can survive almost anything, capitulates to the light. So long as street dust remains what it is—and that will certainly not be always—it is quite bad enough to keep one's outdoor boots on when entering one's home, that should be as sacred a place as the Mohammedan mosque, which the devout will not so profane, but to bring in a skirt that has trailed is dirty, disgusting, and dangerous.

How Architects May Help the Spread or the Prevention of Disease

The other moral to be drawn from the facts is that dark corners should be avoided in the construction of houses. If such corners be necessary they should be rounded and covered with smooth material, so that nothing can accumulate there. We shall never be rid of the national scourge of consumption until many dwellings which do not conform to these needs are razed to the ground; but that is a matter for another section of this work.

From the standpoint of personal hygiene few points need to be added, and none is of such moment as the foregoing. Evidently fog, and whatever ingredients of air obscure the light, are public enemies. The statement recently printed, that doctors are sending patients to certain parts of Sheffield because the smoke is beneficial in certain diseases is the most arrant and egregious rubbish which should be unprintable in these days. Among the numerous objections to smoke is this—that, being of no antiseptic value in itself, whatever may be said to the contrary by the unqualified, it is a direct enemy and barrier to the incomparable antiseptic, which is sunlight. If modern bacteriology knows anything, that one fact settles the case against smoke once and for all.

The Value of Light as a Tonic and the Value of Darkness in Rest

It has been observed that dogs whose eyes were bandaged absorbed 16 per cent. less oxygen by breathing than when their eyes were unbandaged. The observation is interesting, and suggests that light stimulates the respiration. At the same time it must be remembered that a dog has its own *psyche*, and that to have the eyes bandaged must have a depressing mental effect, while it would also tend to restrict movement, upon which the absorption of oxygen so largely depends. But light doubtless does stimulate our activity, and should thus rank as not only the best antiseptic, but as also the best tonic. When we sleep "there is a time for darkness," as has been hinted; and we are justified in carefully excluding the light from our bedrooms if we are indifferent sleepers.

The risks of light are important in some parts of the world, though we scarcely yet know to what ingredient or ingredients of ordinary sunlight the danger is due. These risks, but seldom substantial in our own country, concern the question of clothing, and especially the clothing and screening of the head and the neck, within which lie the most important parts of the nervous system. This point we shall consider later.

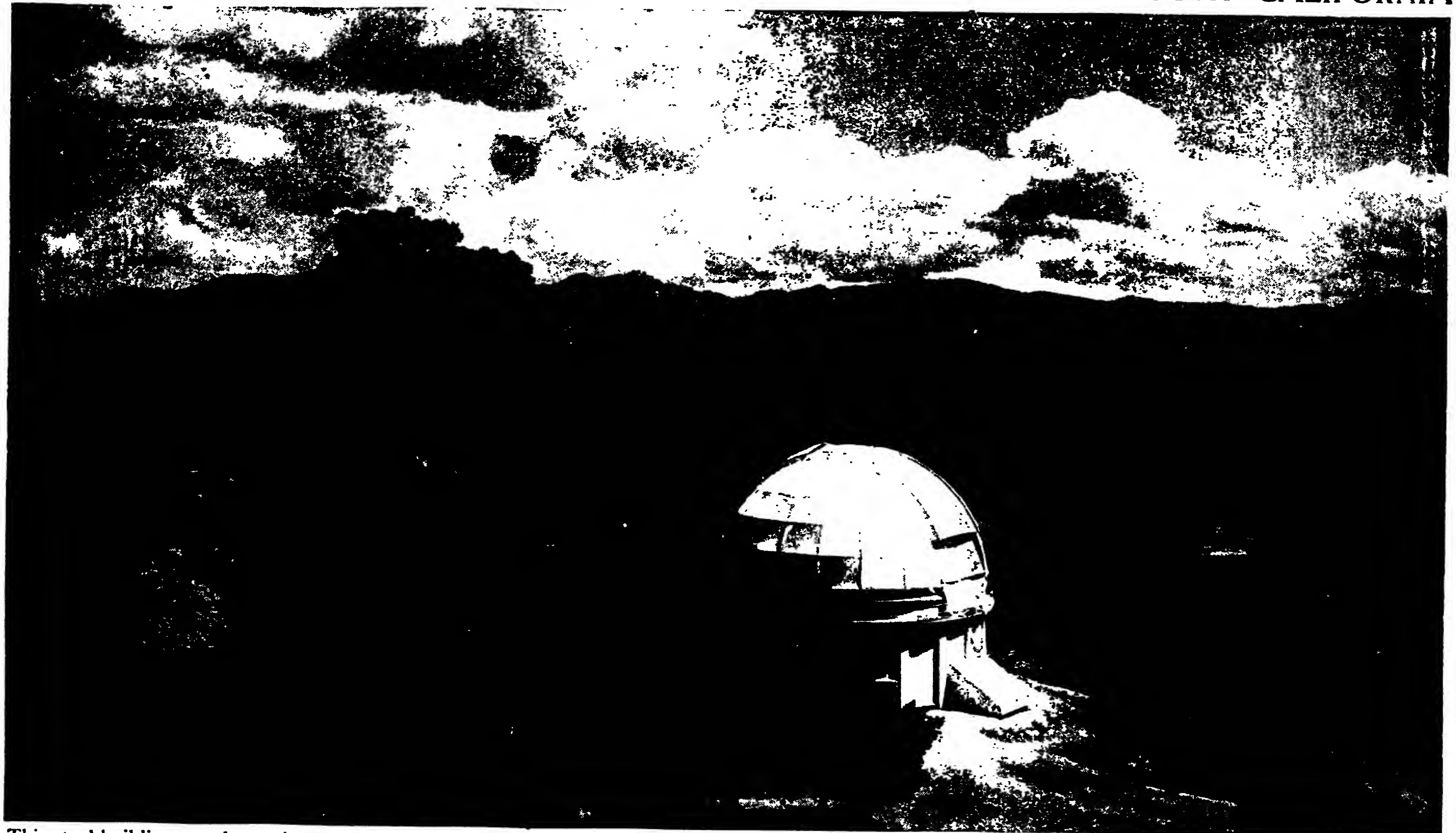
The colouring of the walls of one's home has been briefly alluded to, but it deserves further treatment in relation to the questions of artificial light and the care of the eyes. Here we need only add that if light be good we should have our walls light in colour, so as to reflect the greater part of the light which falls upon them.

Were the Hateful Creatures of Primeval Days the Children of Darkness?

This lightness of walls is also a direct economy so far as the cost of artificial lighting is concerned, for less light will require to be produced. In general, also, it is to be added that the materials and colours of our living-rooms ought not to be favoured and chosen on the ground that they do not show the dirt. If dirt is there, it is better shown and known, for if not it is liable to be ignored, and to breed and harbour microbes wherever darkness permits.

One curious observation may be made in conclusion; so far as the writer knows it is novel. The Creation story of Genesis has frequently been criticised on the ground that it describes the making of the earth before the making of light. But science should not be too sure, for perhaps the order described does indeed correspond to the facts. There may have been darkness upon the face of the deep, and later, in the imagery of Genesis, God said, "Let there be light," and there was light. It may have been during that earlier period, with its opaque atmosphere, that the dangerous creatures which love the darkness and hate the light were first evolved; and the condition of the coming of higher forms was the coming of light. At any rate, the hygienist of to-day can provide overwhelming evidence for the view that the survival of the higher, as against the lower, forms of life depends upon our earnest obedience to the fiat of the Creation story, "Let there be light."

THE SUN OBSERVATORY AT THE SUMMIT OF MOUNT WILSON IN SOUTH CALIFORNIA



This steel building stands nearly 6000 feet above sea-level. The great dome, 58 feet in diameter, contains the 60-inch mirror-telescope, the glass disc of which weighs one ton. To keep the temperature of the building constant the walls are of steel, two feet apart.

CONQUERING THE SUN

The Investigation of the Central Force which Sends Energy Nearly a Hundred Million Miles to the Earth

A TELESCOPE ON A MOUNTAIN TOP

THE greatest problem in astronomy is the evolution of the stars. The star nearest to us is the sun, on which depend the lives of all living things.

Nothing that goes on in the sun is unimportant to us. The cost and the quantity of all our food supplies are directly governed by the amount of sunlight, and perhaps by the amount of electric force, which radiate from the furnace in the heavens, round which our planet spins. If it can be clearly established that there is a close connection between changes in our weather and the regular variations in the shell of the sun, then we may at last be able to foresee the recurrence of bad seasons, and make provision against them.

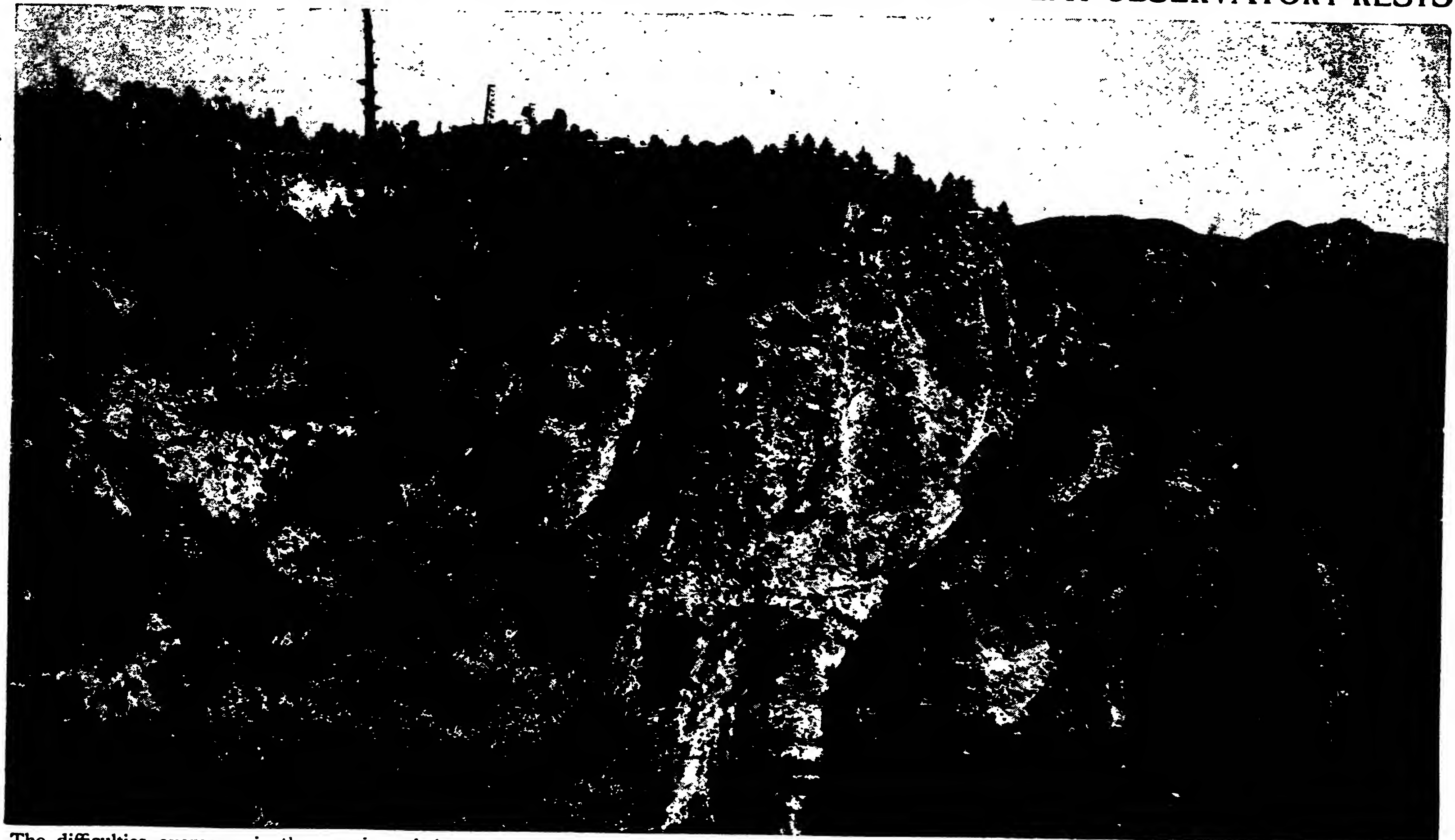
Extraordinary advances have been made lately in our knowledge of the sun; and it is beginning to look as though man, the conqueror of the earth, will eventually obtain sufficient knowledge of the flaming centre of the solar system to make a more scientific use of its terrific forces. At present we lack the power, born of science, which would enable us to foresee what is about to happen. Nearly 93,000,000 miles away from us is a tremendous fire, in the heat and light of which we live, with scarcely any more foreseeing knowledge of it than a kitten has of the kitchen stove by which it basks. It is true that we are aware of the recurrence of the four seasons, but so are the birds that migrate southward to avoid the rigour of winter. Is there anything now going on in the sun that will produce on the earth next summer disastrous weather, poor pasturage, and scarcity of food? This is a question to which no man of science is yet able to give an answer.

Yet much is now being done in the great Solar Observatories, sparsely scattered about the earth, to enable the man of science of the future to forecast the play of some of the vast forces in the sun. Sometimes an apparently useless experiment in electricity, conducted in the underground chambers of a laboratory, helps us to understand what is taking place in the star of our life. For there are strange and mighty manifestations of electric energy in the sun, constituting problems that we must solve before we are able to grasp the knowledge we so ardently desire.

Owing to the enlightened generosity of a number of rich men in the United States, the best means of studying the sun are now possessed by American astronomers. Their instruments of research are the finest in the world. They have quite a considerable number of telescopes of greater power and precision than any in actual use in Europe; and they have applied their native talent for invention in devising new and wonderful apparatuses for ascertaining the actual composition of the sun. By far the most famous of American observatories is the Mount Wilson Solar Observatory, near Los Angeles, California. Only four years have passed since it was partly built, in circumstances of great difficulty; and it is still waiting for the enormous telescope that will complete its incomparable set of instruments. Erected only after a long and heart-breaking struggle against natural conditions, Mount Wilson Observatory has a story which is the latest, and one of the finest, of the true romances of science.

For some years, the astronomers of the Carnegie Institution searched the world for the site of a Solar Observatory which should command a clearer view of the sun than any at present in existence. They went as far as Australia; they glanced at Teneriffe; and at last, in 1904, they chose a mountain in Southern California. Many things had to be avoided. Slight earthquake shocks

THE SHEER MOUNTAIN SIDE ON THE SUMMIT OF WHICH THE GREAT OBSERVATORY RESTS



The difficulties overcome in the erection of the Mount Wilson Observatory were almost inconceivable, all the building materials and instruments being hauled up the side of the mountain.

would disturb the exquisite machinery now largely used in an observatory; bare rocks and earth would absorb the heat of the sun and give out this heat, thus disturbing the air and interfering with telescope work; high-lying clouds would continually obscure the view; and high winds and bad weather would be generally disastrous.

By placing a telescope on a height a mile or two above the sea, we do not, of course, get appreciably nearer to the sun and stars. Light travels at a speed of 186,000 miles a second; it takes about a second and a quarter to come to us from the moon, and about eight minutes to reach us from the sun. To pass, however, across the distance which separates us from the nearest star outside our solar system, it takes about four and a quarter years. And the last theory is that the light from a group of stars on the extreme edge of our universe takes 1,000,000 years to reach us! Standing on a mountain does as little as standing on a mole-heap to bring the stars nearer to our vision.

How the Earth's Atmosphere Shuts Us in from a Trustworthy Study of the Sun

The trouble is the six miles or so of thick atmosphere that envelops our earth. We live at the bottom of a sea of air, which prevents us from viewing clearly everything beyond it. It is air that makes the stars seem to twinkle, though they are really steadily flaming suns; it is the air which absorbs many of the shorter light-waves, and gives us a wrong impression of the heavenly bodies. Especially is this so where modern photographic methods of study are employed. It is the shorter waves of light—blue, violet, ultra-violet—which affect a photographic plate, but the air stops these more than it does the long, red waves of light.

For these reasons, altitude is of great importance to astronomers. A mountain lifts them above the thick layers of air, and enables them to make more delicate and exact observations. Mount Wilson, which has been selected as the site for an observatory using the largest and most powerful telescope in the world, is one of the many heights that form the southern boundary of the Sierra Madre range. Standing at a distance of thirty miles from the Pacific Ocean, it rises nearly 6000 feet above the green ranches and towns of Southern California. The view southwards reaches to Mexico, and seaward it extends to islands in the Pacific one hundred miles distant. To the north, bare vast ranges of rugged heights shut out the Mojavo Desert, but near at hand the high lands are covered with pine-trees, that march forward and climb to the summit of Mount Wilson. It is not many years since a band of horse-thieves used this wild, beautiful, and secluded spot for their operations between the Mexican border and San Francisco. A trail, 2 ft. in width and 9¼ miles long, connected the top of the lonely mountain with the plain beneath, when the astronomers began to build their observatory about seven years ago.

Fighting the Battle of Scientific Observation Against Fierce Onslaughts of Weather

Hundreds of tons of building material had to be carried up this steep and narrow trail. Bit by bit it was packed on donkeys and mules, and sent up the mountain. It was very slow work, and very troublesome, and the trail was at last widened to admit of horses being employed. But even horses took fifteen hours to ascend and descend the mountain; and they could draw so little that they had to make sixty round trips merely in taking the mirrors, lenses, and castings of two telescopes and the steel skeleton of one of the telescope-houses. For two years the work was carried on in this way, and progress was naturally slow. So, in the autumn of 1906, building operations were suspended, and all the labour available was used in widening the trail into a waggon road. Then came a heavy misfortune. A wild snowstorm buried the top of the mountain under snow, which lay five feet deep in the level parts, and very much deeper in other places. In the spring of 1907 the snow began to melt under torrential rains, and thousands of tons of earth and rock swept in destructive avalanches down the steep slopes.

A Glorious Triumph of Human Endeavour for the Most Disinterested of Purposes

However, the road was remade, and by the middle of 1907 a good part of the Observatory was built, in spite of the fact that a fire broke out, through an overheated stove, and destroyed all the houses of the astronomers and their assistants. At the present time, there are sufficient instruments at Mount Wilson to enable the men of science there to undertake new and extremely valuable researches into the evolution of the stars. Misfortunes, however, still accumulate around the Observatory, and the great telescope has not yet been constructed. All its mountings have been finished for some years, but attempt after attempt has been made to cast the enormous mirror, and each attempt has failed. Dogged perseverance, combined with the highest scientific

attainments and extraordinary engineering skill, must surely triumph in the end. Already Mount Wilson is a glorious monument of human endeavour applied to one of the highest and disinterested of ends; and the story of its conquest is one of the most romantic things in the annals of modern science.

Ideal Conditions of Observation in Thin Air Far Above Earth's Exhalations

The climatic conditions have been found to be perfect. From April to August, fog rolls in from the ocean, and at night covers the wooded slopes. But the fog-cloud seldom rises higher than three thousand feet. Far below the Observatory it stretches—a strange, dim, tumbled sea, breaking against the dark heights, and shutting out every glimpse of earth. The moonlight turns it into a floor of pearl and silver; as it lifts and scatters at daybreak, the rising sun colours it with tints of lilac, rose, and gold.

By night, the gorgeous over-arching sky is of a wonderful transparency; the stars have an unearthly brightness and a marvellous beauty. Very near they seem, even to the naked eye. By day the heavens are of a very deep blue colour, and in the thin, pure air the sun puts on a dazzling brightness. During many months of the year the sunshine is continuous; and though in summer the sea-breeze blows for a part of the day, it has a low speed, and slackens still more in passing from the valley to the mountain top. Many of the buildings of the Observatory, and particularly the towers in which instruments are fixed, are constructed of a skeleton of steel or iron. The wind blows through the structure, instead of beating against a solid wall of brick or stone. In this way vibration is much lessened; in fact, in ordinary weather it is not felt at all.

Towers Within Towers that Guard the Most Delicate Instruments Against Vibration

The most remarkable of the towers is that which was built in 1910. It stands a hundred and sixty feet above the ground, and beneath it is a large well seventy-eight feet deep. Each of the steel members of the tower is guarded from the wind by being enclosed within an outer tube of steel, and separate foundations of concrete are made for the inner and outer portions. There are thus two towers, one within the other. On the inner tower are fixed the two mirrors of the telescope. The beam of light from the mirrors is sent straight down into the well beneath the tower. To protect the beam from disturbing air-currents, it is enclosed in an iron tube, five feet and a half in diameter; the tube is lined with sheet-iron and covered by a canvas shield. In the well, where the tube ends, is a set of mirrors which catch the beam of light and reflect it on to various instruments. By this means a very large image of the sun is obtained. This image must not change its position one thousandth of an inch. That is why extraordinary precautions are taken to build a telescope that shall not vibrate in the least.

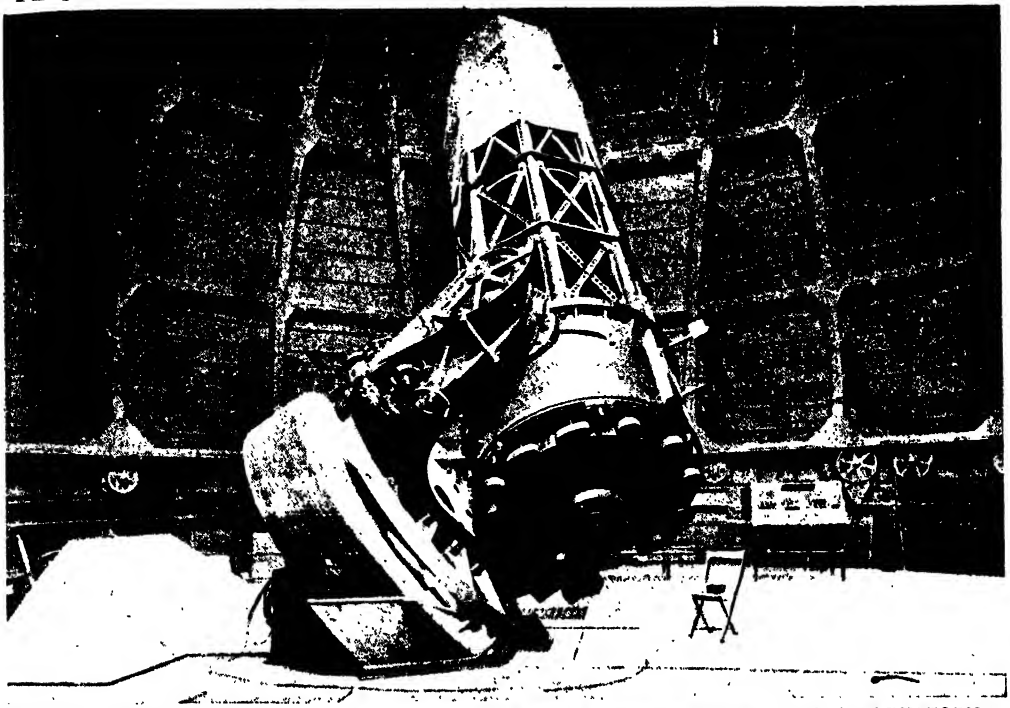
Yet an absolutely fixed telescope has a grave defect. It cannot be shifted so as to follow the movement of a heavenly body. So a new instrument called a cœlostat is used on Mount Wilson. It consists in principle of a set of revolving mirrors; and its position can be altered so as to reflect any portion of the sky on to the lens of the fixed telescope. The mirrors stand in the opening of the dome, and they can be moved about on rails and adjusted to any position. They are twelve inches thick, and they are encased in closely fitting water-jackets, through which a stream of water is kept circulated. This is done to prevent the mirrors from getting hot. For heat makes the glass swell and disturbs the reflecting surfaces, with the result that the beam of light thrown into the telescope is so distorted that a useless image is sent down into the well.

A Gigantic Mirror so Delicate that the Heat of a Man's Body May Mar Its Work

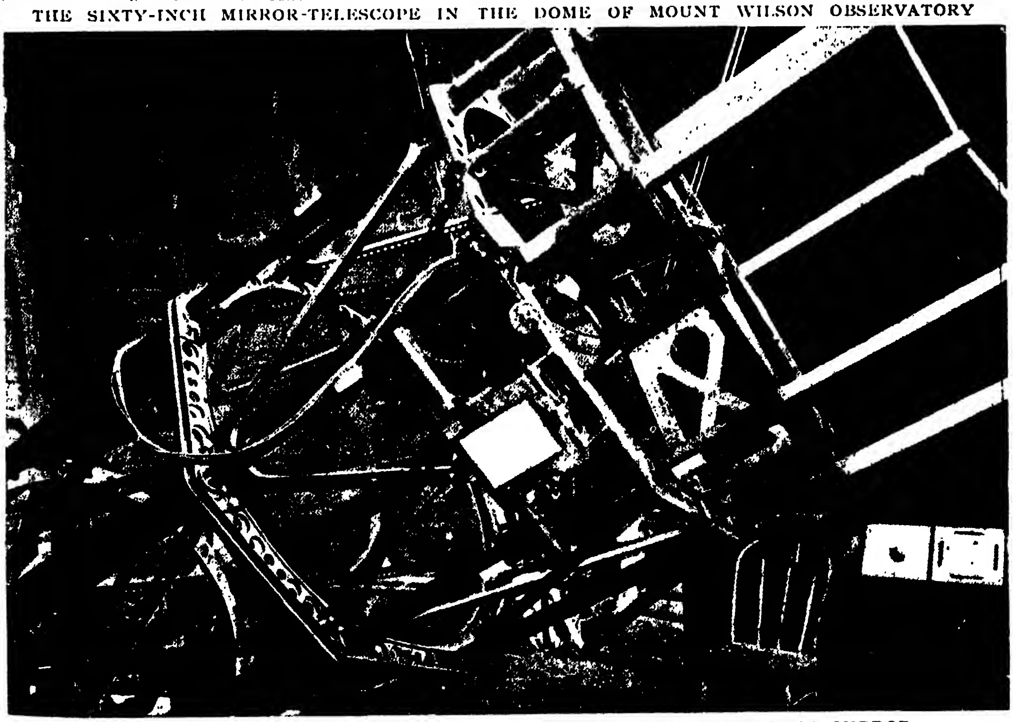
The distortion of mirrors is the greatest problem that disturbs the minds of the men of science on Mount Wilson. Fires, snowstorms, and avalanches are trivial events when compared with the trouble with the mirrors. Sometimes a tempest of wind is less distracting than the natural heat of a man's body as he stands by a telescopic mirror, intent on examining the image of the sun in it. In the greatest telescopes used at the Observatory there is no system of lenses and no hundreds of feet of tube. The telescope consists merely of a huge glass mirror. That now in use weighs a ton, without any of its mountings. It is five feet across and eight inches thick, and is made of plate glass.

There are two kinds of telescopes, the refracting and the reflecting telescope. An ordinary opera-glass or an ordinary field-glass is a refracting telescope; so is any telescope in which a lens is used. The lens, which in its simplest form consists of a round piece of glass with a convex or bulging surface, bends or refracts the rays

HOW THE SUN IS PHOTOGRAPHED



THE SIXTY-INCH MIRROR-TELESCOPE IN THE DOME OF MOUNT WILSON OBSERVATORY

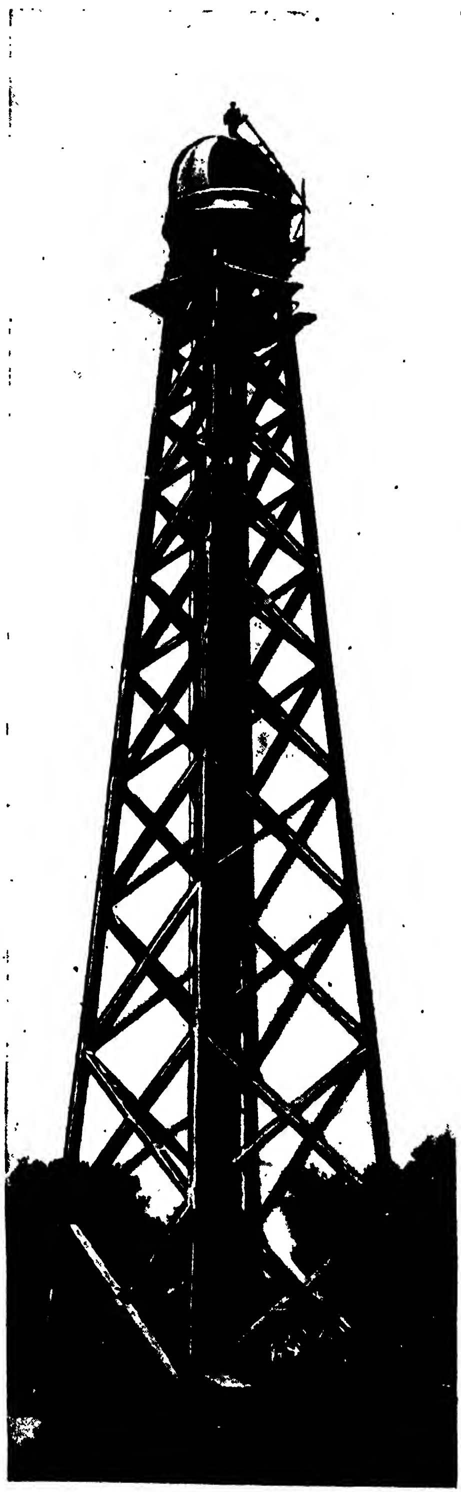


THE PHOTOGRAPHIC CAMERA IN THE FOCUS OF THE REFLECTING MIRROR

The upper picture shows the great sun telescope, and the machinery that moves it. The steel framework in the middle of the telescope supports mirrors which receive reflections from the big 60-inch mirror in the base of the telescope. These mirrors reflect light out of the frame into spectroscopes, or a photographic camera, as shown in positon in the lower picture.

of light that pass through it. The largest practical telescope in which lenses are fitted is the Yerkes telescope, near Chicago. The Yerkes lens is forty inches in diameter; the front glass is made of crown glass; the inner glass is made of flint glass, and they weigh together about five hundred pounds. The lens is of extraordinary purity and transparency; but, as it is three inches thick, it absorbs a considerable amount of light. The lens unfortunately acts as a prism, and bends the different coloured light-waves in different directions, thus producing several coloured images of one object instead of a single white image.

This is the fault of all refracting telescopes; and Sir Isaac Newton, who was the first man to discover the cause of the fault, managed to get rid of it by inventing the mirror-telescope. He placed a mirror, which was formed of metal and hollow or concave in shape, at the bottom of a tube. The light fell on the highly polished surface, and from there it was reflected to a little mirror near the top of the tube. In the side of the tube opposite to the little mirror was a hole; in this hole the eyepiece was fixed. The beam of light fell on the large mirror; the large mirror reflected it on to the little mirror; and the little mirror transmitted it to the eyepiece. In this way the waves of light were kept from being broken up by

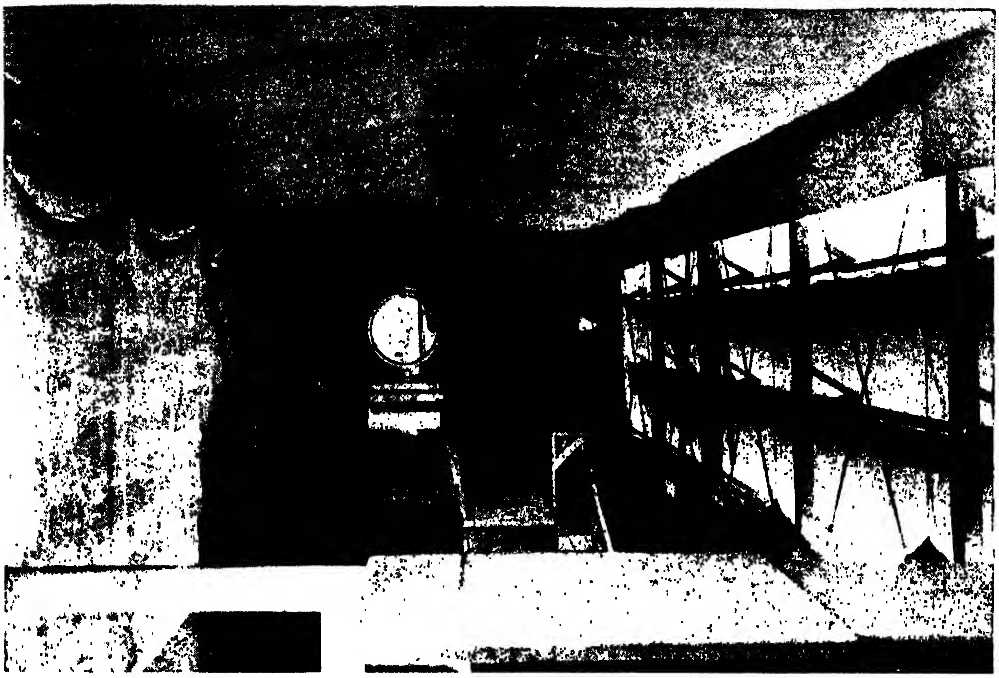


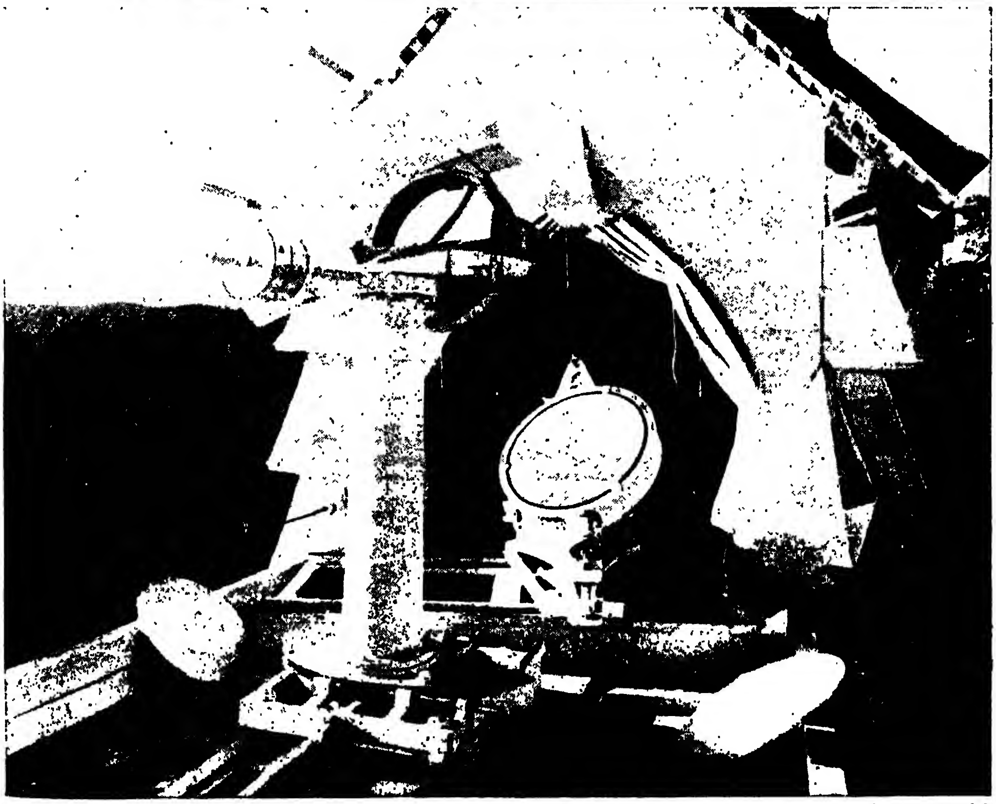
ONE OF THE GREAT TOWERS OF THE SUN OBSERVATORY

passing through a glass lens.

Unfortunately, the little mirror which was placed in the middle of the tube cut off a great deal of light; and, moreover, the polished metal surfaces could not be made to reflect as much light as a piece of transparent glass will let through. So what was gained in not breaking up the light-waves was lost partly through the arrangement of the mirrors, and partly through the defects of the reflecting surfaces. Metal mirror-telescopes, however, can be made much more cheaply than refracting telescopes, and some fine work has been done with them.

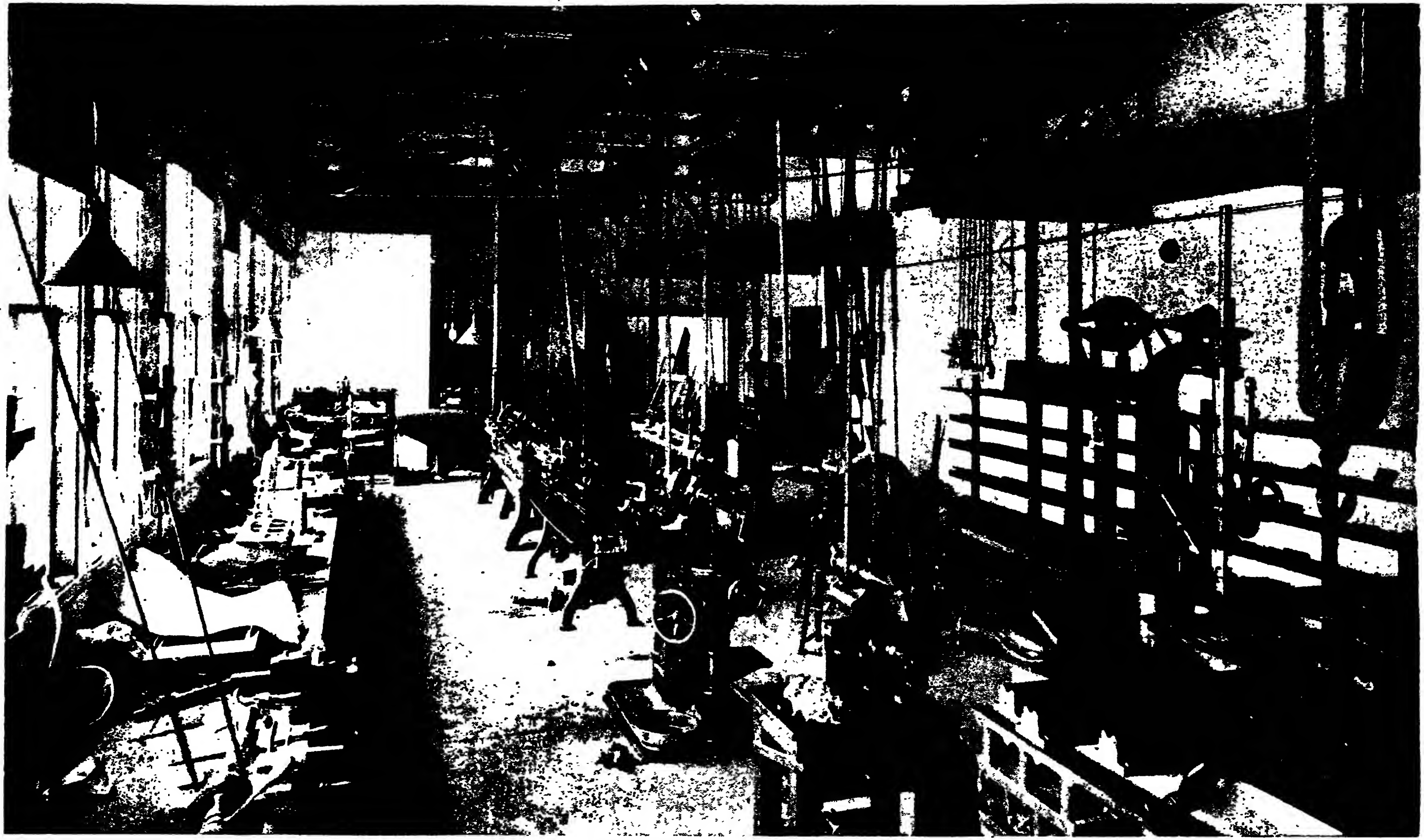
The Earl of Rosse, for instance, constructed, in 1845, at Parsonstown, in Ireland, a mirror-telescope that has a diameter of six feet. It is still the largest in the world, for Mount Wilson Observatory is waiting for its 8¼-feet telescope. The Rosse telescope consists of an enormous tube, at the bottom of which is a huge mirror of metal. At the time it was constructed, engineering methods were inadequate to provide a proper mounting for so gigantic an instrument. It was swung in chains, and flanked by two stone walls that greatly restricted its range, yet some remarkable discoveries were made by means of it. The observer stood upon a platform far above the ground, and, looking down into the tube, saw there the image of the object. It was impossible to maintain the





Light from the sun strikes the Snow cœlostat, the lower mirror shown in the bottom picture, and is reflected to the plane mirror above it. This mirror reflects the light on to a concave mirror 145 feet away, at the end of the canvas-covered interior shown in the upper picture.

INSIDE THE WORKSHOP OF THE GREAT SUN-OBSERVATORY



In this busy workshop are installed the most elaborate machines of precision used for making many of the accurate instruments employed in the Observatory.

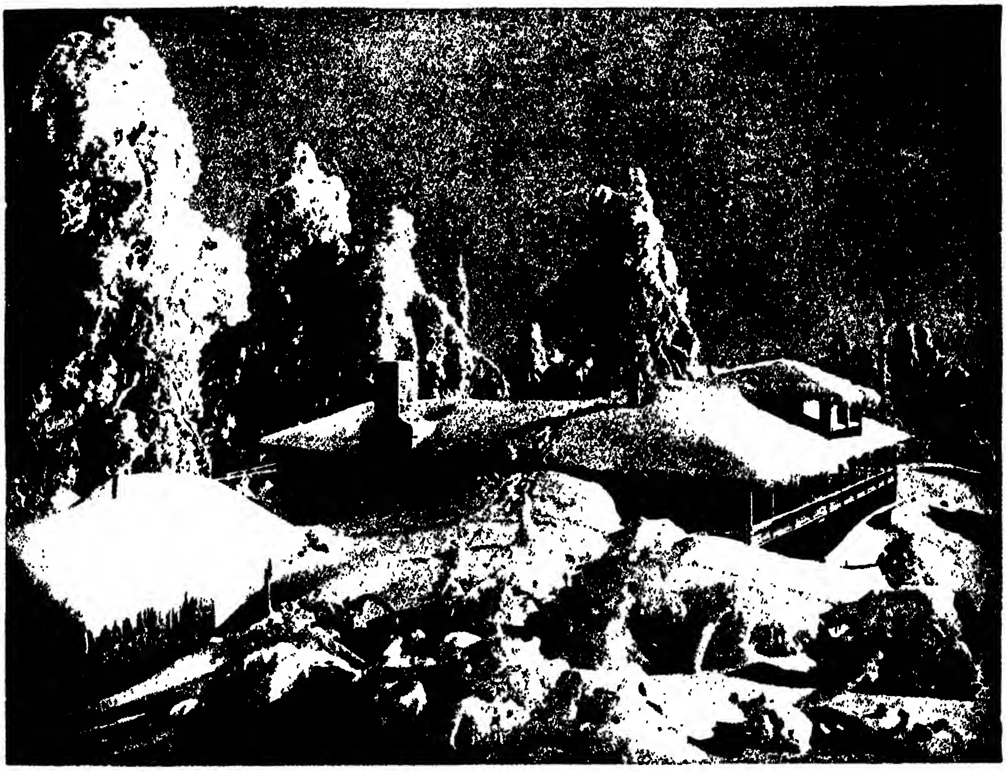
telescope steadily fixed for hours at a moving star; and it was impossible also to make accurate measurements with it.

Now, however, it has been found that a glass mirror-telescope only 23½ inches in diameter can take photographs of star-mists which are at the extreme limit of vision of the very best 40-inch refracting telescope This was found out in 1897, when Professor Ritchey, who is now working at Mount Wilson, made a glass mirror for the Yerkes Observatory, and helped to design a very ingenious mounting for it.

It is due to the genius and ingenuity of Professor Ritchey that the first great telescope of the modern kind was fixed on Mount Wilson in 1907, in the year of the great snowstorm. This telescope is named after Miss Helen Snow, of Chicago, who gave the Observatory £2000 towards the cost of it. The glass mirror, as we have said, weighs one ton, and it was cast by the French Plate Glass Company of St. Gobain, France—the only firm in the world with the plant for making discs of this magnitude. After being carefully tested in the workshop of the Observatory, it was found to be apparently perfect, but when Professor Ritchey began to grind it it suddenly flew to pieces

This is the great trouble with these huge glass mirrors. The glass has to be perfectly annealed, and no strain must be found in it. That is why there is so much difficulty over the 4½-ton mirror, with a diameter of 8⅓ feet, for which Mount Wilson is still waiting. Again and again the disc has been cast and annealed, and again and again it has broken The Mount Wilson astronomers have journeyed to the works of the French Plate Glass Company and there devised novel kinds of apparatus for making the great disc, but the old trouble remains when the men come to anneal the glass.

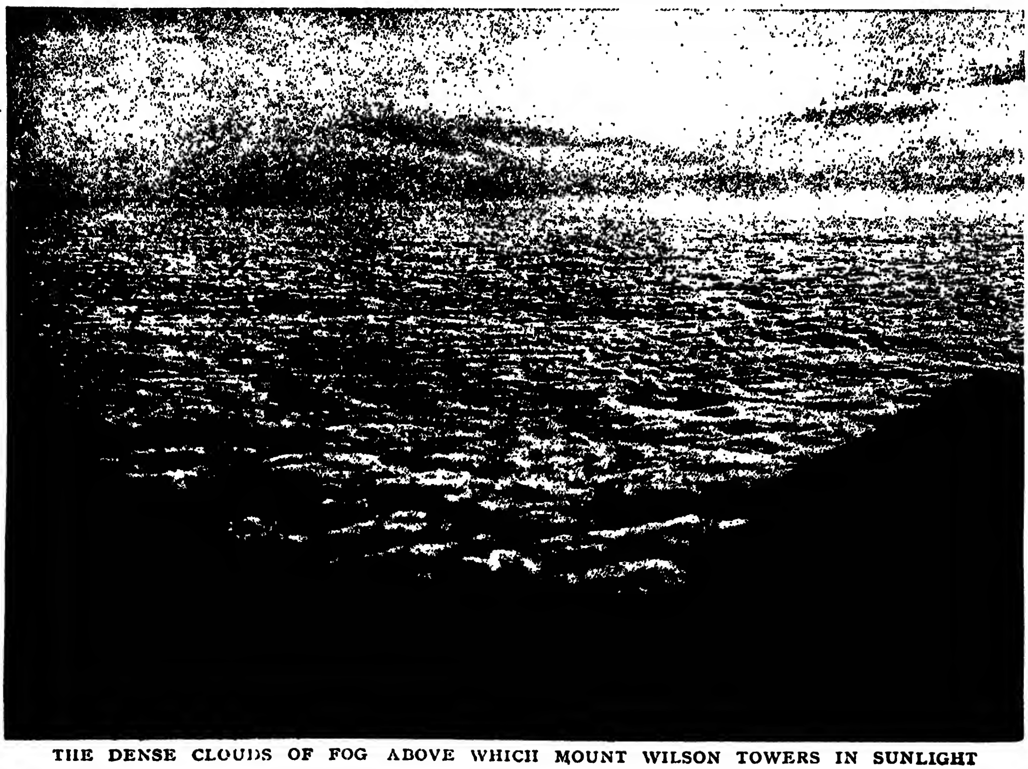
So the greatest of all telescopes has not yet come into existence. Everything is ready for it at Mount Wilson—a special grinding-machine and a special mounting, and a large fund of money provided by Mr. John D. Hooker, after whom the telescope will be named. Surely there never was an institution of science which has had to fight against so many difficulties as the Solar Observatory at Mount Wilson. The fact is that its leading men have, from



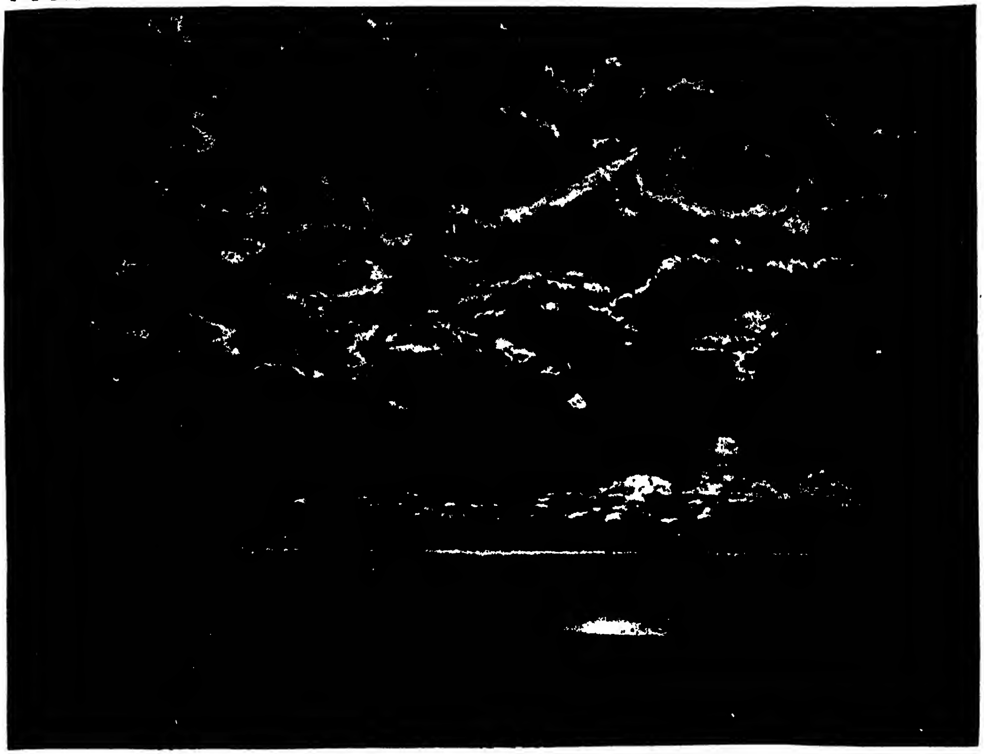
THE WINTER BEAUTY THAT SURROUNDS THE OBSERVATORY AT MOUNT WILSON

THE SEAS OF FOG THAT LIE ABOVE THE CLOUDS

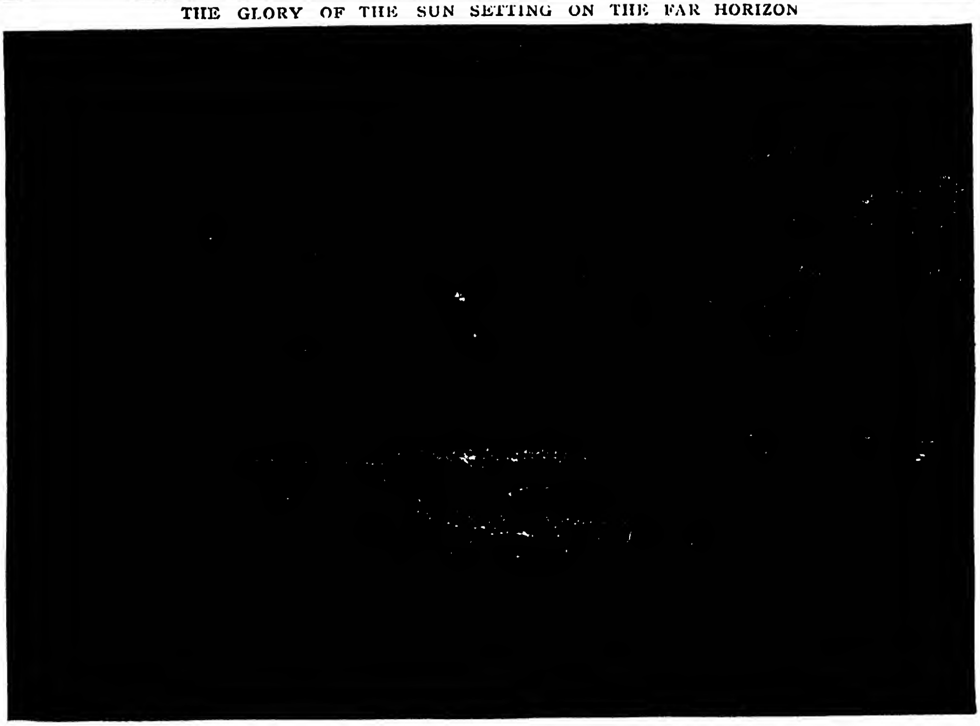
THE SUNNY SIDE OF FOG—A BANK OF MIST VIEWED FROM MOUNT WILSON



THE DENSE CLOUDS OF FOG ABOVE WHICH MOUNT WILSON TOWERS IN SUNLIGHT



THE GLORY OF THE SUN SETTING ON THE FAR HORIZON



THE LIGHTS OF TOWNS SEEN THIRTY-EIGHT MILES AWAY

These two striking photographs were taken by night from the heights of the Mount Wilson Observatory, in Southern California.

the start, been bent upon making every possible advance in the means of astronomical study. Each of these advances they have won by long and painful labour and new experiments. Most of them are men trained in the Yerkes Observatory; and in them is displayed at its best the American spirit of enterprise and persevering audacity. Already their Observatory has become the world-centre of the study of the sun and the evolution of the stars.

The Photographic Plate that is Steadier Than the Hand and Never Grows Tired

Here the Snow telescope, and the wonderful instruments attached to it, are of incomparable value. The great telescope is hung between the arms of a massive cast-iron fork, and pointed through an opening in the dome of the Observatory. The dome is worked by electric motors, so that the opening in it also follows the course of the object which the clock-driven mirror telescope is photographing. Between the dome and the floor hangs a platform, and here the astronomer stands, looking into a second mirror. This second mirror receives the image formed by the great five-foot mirror at the end of the tube. Opposite to the second mirror is a double slide plate carrier, fixed on to the skeleton framework of the tube. The image is projected on to the plate, and photographed.

Nearly everything is done by photography in a modern observatory. The photographic plate is steadier than the human eye, and it never grows tired. Moreover, it can record waves of light which are invisible to us, and trace the path of myriads of stars which we cannot see even through the most powerful telescope. The most remarkable of all photographic instruments is that invented by Professor George Ellery Hale, the Director of the Mount Wilson Observatory. It is called a spectroheliograph, and is used for taking photographs of the sun by the light of a single element flaming on the solar surface.

The Wonderful Instrument which Picks Out a Single One of the Sun's Rays

As is well known, light can be broken up into a band of rainbow colours by passing it through a three-sided piece of glass. This band of colours is called a spectrum. The curious thing about it is that it is full of dark lines as well as tints of colour.

By a discovery already described, on page 202, it was found out that the dark lines in the spectrum of sunlight or starlight represented the various elements which were burning in the far distant heavenly bodies. The line in the spectrum representing helium, which is one of the elements into which radium decomposes, was found in the sunlight spectrum, and also in some stars, many years before the actual substance was discovered on earth. The spectroheliograph devised by Professor Hale takes a photograph of the sun with a single light-ray proceeding from only one of the many elements which are flaming together and flooding the earth with sunshine. In this way it is possible to obtain a large and exact photograph of, for instance, all the lime which is blazing on the surface of the sun. Or the lime-ray can be shut out, and only the ray produced by the iron whirlwinds in the sun can be photographed.

This is how it is done. The large solar image from the great telescope is made to move across a narrow slit. Behind the slit is a prism of glass, which breaks the light up into a long band of spectrum colours. The spectrum is thrown on to the lens of a camera tube. Behind the lens is another slit, and behind the slit is a photograpic plate. The photographic plate is mounted on a carriage which runs on rails, and it is timed to move exactly at the same rate at which the solar image from the telescope moves across the first slit.

How a Photograph of the Sun May be Taken to Show Only One of Its Elements

The delicacy of the operation is mainly a matter of adjusting mirrors and lenses so that only a certain line in the twenty thousand lines of the spectrum enters through the photographic slit. This adjustment is, of course, made before the solar image and the photographic plate are set in motion.

Let us suppose that Professor Hale wishes to take a photograph of the sun by the light of the flaming lime in the sun. In the extreme violet region of the spectrum there are two broad, dark bands known as H and K. These represent calcium, the metallic base of lime.

The telescope is directed at the sun, and the image formed is thrown on a prism, and there broken into a band of colour, which is reflected on the lens of the camera, and from there thrown on the screen in the middle of which is a slit. Then either the telescope or the prism of glass is moved until the two lines H and K fall exactly through the slit on to the photographic plate—all the rest of the lines and colours being blocked out by the screen. When this has been done the double movement of the solar image and the photographic

plate is started. The result is that every wave of light created by the burning lime in the sun strikes against the photographic plate as the solar image is slowly moved across the slit of the prism

To put it roughly and briefly, the sunlight is broken up and then filtered, and only that fragment which represents some special element is allowed to pass through the filter and record itself upon the plate Thus is obtained a picture of the sun lighted by the rays from a single element burning there.

By means of the spectroheliograph, astronomers are now able to analyse the sun more easily and exactly than a chemist could analyse a furnace a few years ago. For Professor Hale has now improved his wonderful instrument, so that it gives a photograph of vapours of a single element lying at a low level on the sun, light-waves from the same vapours at a high level being blocked out with the rest of the spectrum. Thus the true structures of the solar phenomena are now being discerned; and some of the most fundamental problems of the universe are in a way to be solved at the Observatory which was built with immense difficulty on the summit of Mount Wilson.

Differences of temperature on the surface of the sun can now be distinguished by means of the spectroheliograph; and it is hoped that this new knowledge will prove of great value in examining the vapours associated with sun-spots. Heliographs are now used daily in England and India, Sicily, Spain, and Germany, France and the United States. The observatories in which they are employed are connected together in a Solar Union, which is making a combined attack on the sun from different parts of the world In time, very important additions to our knowledge of solar phenomena will be obtained; and perhaps we shall then be able to forecast to some extent the play of some of the forces in the sun which vitally affect the life of everything on our earth.

A STORM IN THE MOUNTAINS, AS SEEN FROM THE SUN OBSERVATORY

Much continuous daily research in all the Solar Observatories is still required. For instance, there are twenty thousand lines in the spectrum of sunlight, and each of these lines needs to be examined over and over again with the spectroheliograph before we obtain separate photographs of the substances of the sun. We already know a great deal about the lime and hydrogen and iron burning away in vapour at various levels above the solar shell. It is probable

that the enormous heat of the sun results in combinations of substances which we cannot imitate in our laboratories. Already, however, Sir J. J. Thomson has discovered how to create hundreds of new forms of matter by sending a current of electricity through a vacuum tube into which just a little gas has been admitted. Men of science now are also examining deeply into the electrical disturbances produced by heat. Thus in various ways we are gradually coming to understand the theory of what takes place in the gigantic furnace of the sun. Possibly we shall never be able to reproduce in any experiment all the conditions of solar heat.

The Inconceivable Forces Set in Play on the Surface of the Sun

The forces set in play merely on the outer portions of the sun's globe are simply inconceivable. Perhaps the explosion of cordite, when one of the thirteen and a half inch guns of the Orion is fired, is as striking an example of the force of ignited gases as we are familiar with. Now, suppose that every foot of space in the county of Yorkshire were covered with such guns, all pointed upward, and all being discharged at once. The result would compare with what is going on in the sun as a boy's popgun compares with the big guns of the Orion.

Perhaps the most immediate problem in regard to the sun which the Solar Union is tackling is that relating to variations of heat. We can take it for granted that the sun will continue to radiate heat for many centuries to come at practically the present average rate. But do we know that the rate is absolutely constant? May not fluctuations occur of sufficient magnitude to affect our climate, and to be reflected in change in the quantity of crops and the price of wheat?

Has a Spot on the Sun Anything to Do with the Price of Wheat?

Until a short time ago this question had been tested in only the roughest way. It was known that sun-spots passed through a regular cycle of change, occupying about eleven years. A curve was accordingly drawn, showing the varying number of sun-spots, and this curve was compared with the curve representing the varying price of wheat. As the two were thought to show some correspondence in form, it was held that the price of wheat was determined by the solar activity as measured by the number of spots.

The whole question, however, is still in its primitive stages, and little has been learnt yet which is absolutely definite and trustworthy. The Solar Commission of the International Meteorological Committee is making an effort to obtain throughout the world sufficient information for a general statement. Work of special importance is being carried on at the Mount Wilson Observatory with very ingenious apparatuses. At regular intervals throughout the day the image of the sun from one of the great telescopes is split up into the band of colours of the spectrum, and this band of colours is made to move slowly over an instrument which can record the heat of a candle at the distance of a mile. In other words, the instrument measures a rise in temperature of less than one millionth of a degree. It is called a bolometer, and we have already described it on page 210.

The measurements were begun in 1905; and as the cycle of changes of sun-spots occupies a little over eleven years, we must wait until 1916 for a complete report of the Mount Wilson observations. Moreover, the events of the present cycle will have to be compared with the events of the cycle ending in 1927, before we can be sure that we are in a way to discover that law of the variations of the heat of the sun which will enable mankind to become more the master of its immediate fate than it is now.

The Extraordinary Changes that May Take Place in the Inside of the Sun

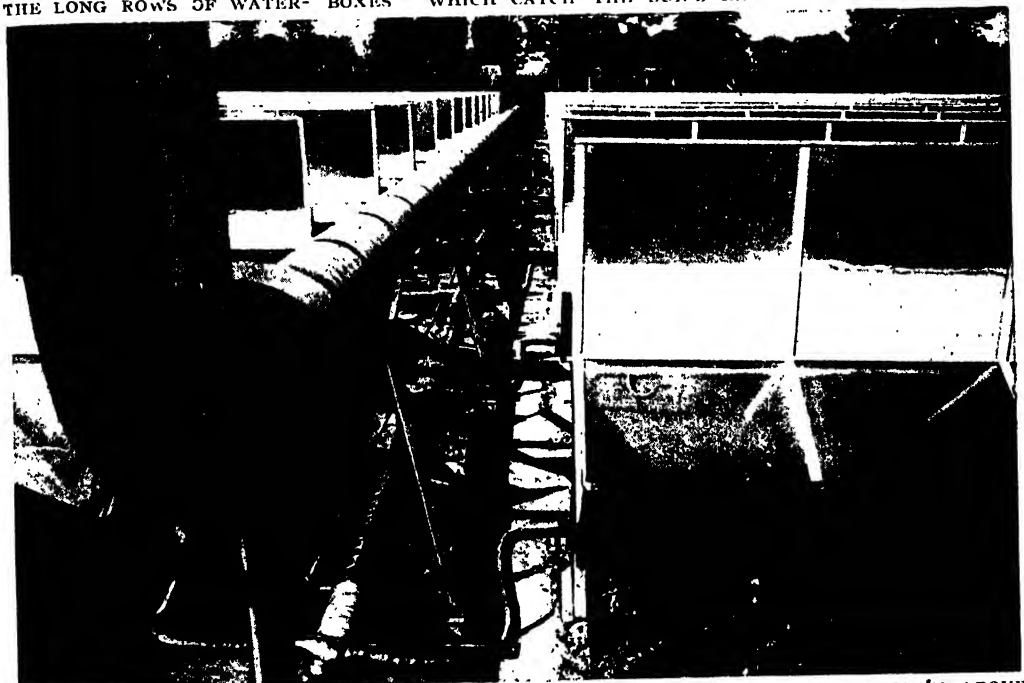
From the results obtained it seems likely that the solar heat temporarily undergoes actual change which is not to be ascribed to any modification of our own atmosphere

Photographs taken of the sun's surface by means of the spectroheliograph seem to show that these changes of heat are brought about by violent currents which convey large quantities of heat from the depths of the sun to the exterior. But the problem is not simple. For the increased radiation produced by great solar activity may quickly be checked by the diffusion, through the atmosphere of the sun, of the materials thrown upward by the violent eruptions. Simultaneous observations at several widely separated mountain ranges are greatly to be desired. By this means it would be possible to ascertain if local changes in the earth's atmosphere are in any way concerned in the apparent solar changes.

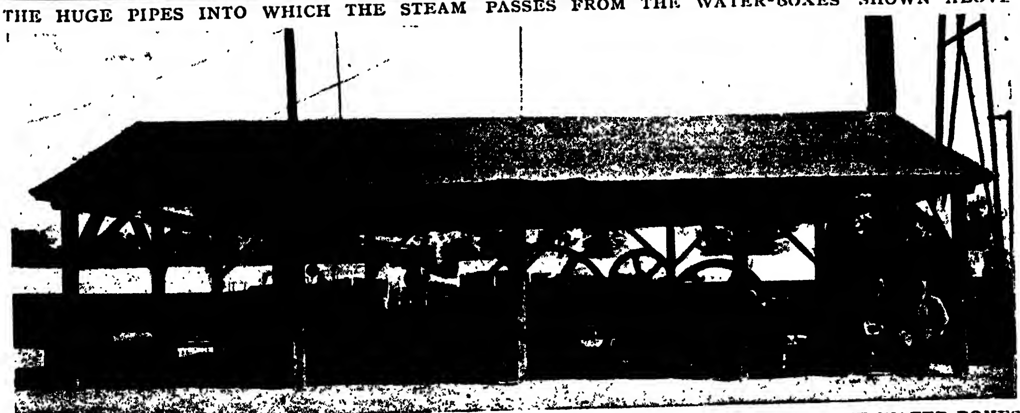
Moreover, the work should go on without the interruptions caused by the rainy season. For example, when the rains begin to fall at Mount Wilson, there is a dry season at the Solar Observatory at Kodiakanal, in South India, which has an

THE SUN'S RAYS HARNESSED TO AN ENGINE

THE LONG ROWS OF WATER-"BOXES" WHICH CATCH THE SUN'S RAYS TO GENERATE STEAM



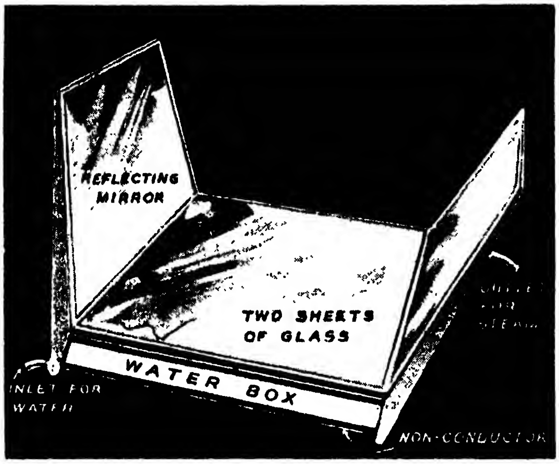
THE HUGE PIPES INTO WHICH THE STEAM PASSES FROM THE WATER-BOXES SHOWN ABOVE



THE ENGINE DRIVEN BY THE STEAM GATHERED INTO THE GREAT PIPE FROM THE WATER-BOXES

elevation of 7000 ft. So the astronomers of the two observatories could co-operate in studying the variations of solar heat, special regard being given to a standardisation of the bolometers and other instruments of measurement. An Australian station would also greatly help in accomplishing very important results, and it is hoped that provision may soon be made to establish such a station.

It might be thought that if there are real fluctuations in the sun's heat, which cause marked changes in the temperature of the earth, the effect would be obvious and easily detected. But, as a matter of fact, the atmosphere and the weather of our earth form a very complicated mass of phenomena, in which the sun's varying heat is only one factor. The rotation of the earth, the dip of its axis, the pull of the moon, and several other things may produce effects of a very complex kind. These effects have to be traced and disentangled before we can clearly discern the part played by fluctuations in the solar heat on our weather. Studies of the solar radiation have been undertaken by the Solar Union, and co-operation in the science of weather has been started by the Solar Commission. Thus there are many investigators now engaged in an exhaustive study of one of the most practical and important points in astronomy. The work, however, is barely begun. It must be continued for many years before it can have a direct effect upon the lives of the whole of the human race.



THE CONSTRUCTION OF ONE OF THE WATER-BOXES OF THE SUN-POWER-ABSORBING APPARATUS

While an army of astronomers is attacking the problem of the sun, with a view to obtaining useful knowledge of the play of its tremendous forces, a troop of inventors has, for the last sixty years, been trying to make direct use of the heat of the sunlight. From 1850 till 1880, one of the periods of most ingenious invention, scores of patents were taken out for engines designed to work with sun-power, but all these inventions were of little or no practical value. Now, however, when general interest in the matter has completely died away, Mr. Frank Shuman, of Philadelphia, has suddenly amazed the world by constructing a sun-power plant which promises to turn the deserts of the tropics into centres of industrial activity. One of his sun-engines has recently been completed, and tested in Philadelphia, and it is about to be used in Egypt for pumping up water. It can lift 3000 gallons of water every minute to a height of 33 ft., when working in favourable weather at Philadelphia. In the hotter climate of Egypt it will naturally do much more work in the same time.

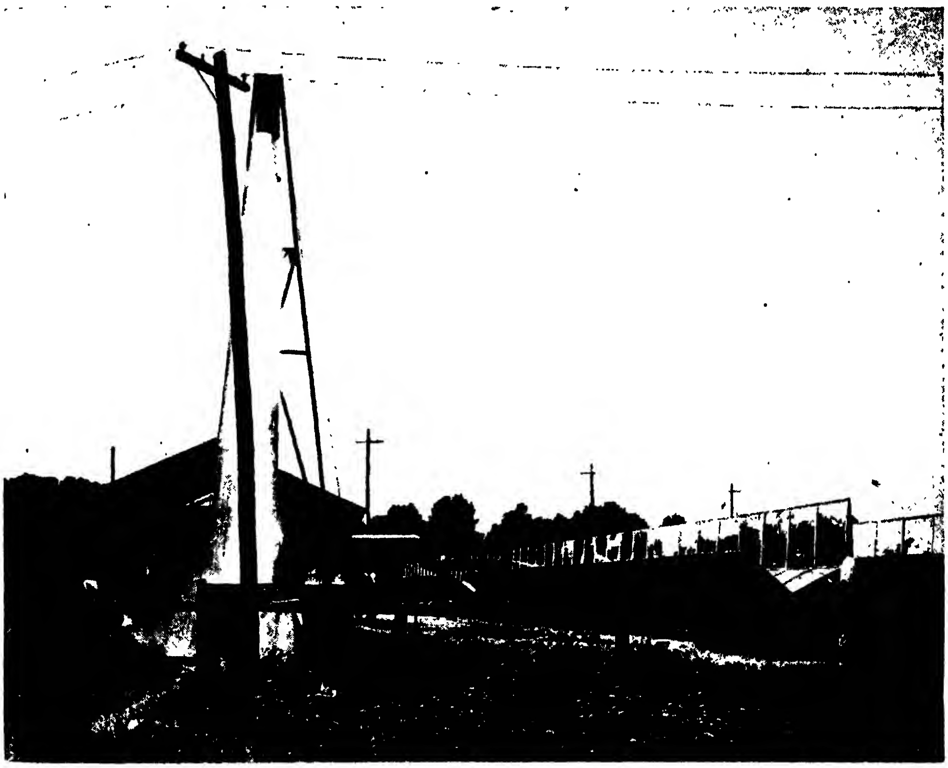
The most important feature of a sun-engine is the steam-generator. Not only must it absorb all the heat it can from the sun, but, having obtained this heat, it must lose as little as possible. In other words, it must be a good absorber and a bad radiator; and these are two qualities which are very difficult to combine. A black surface is the best absorber of heat, and a bright surface is the best retainer. The problem before Mr. Shuman was to unite these two surfaces in a steam-generator.

This is how he did it. He made a flat box of sheet iron, 3 ft. square. The top of the box was covered by two panes of window-glass, separated by an air space of one inch. On either side of the top of the box were two mirrors, placed slantingly so as to collect the sunlight and reflect it on to the sheets of glass. The interior of the box was painted a dull black, with a paint which did not reflect more than six per cent. of the heat-rays; and a frame of stout wood enclosed the apparatus, and helped to prevent the heat getting away. On one side of the box was a pipe through which water could be admitted; and on the other side was a pipe from which steam could be conveyed.

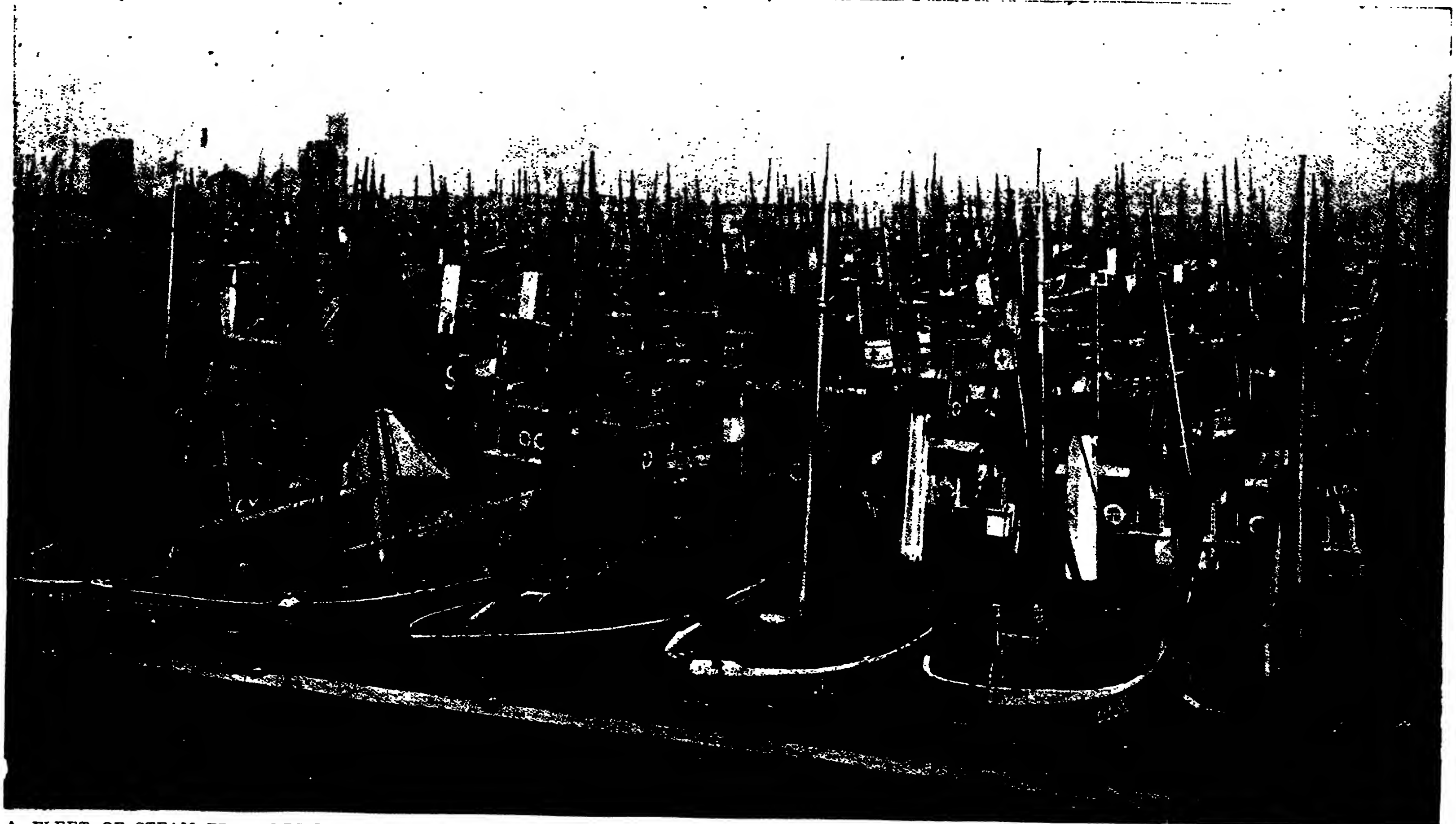
When the box was placed in the sunlight and filled with water, it became a steam-boiler. The two mirrors concentrated the heat of the sun on to the two plates of glass.

The water beneath grew warm, and gave off steam, which passed away through the steam-pipe. In the engine which Mr. Shuman has built for Egypt, the boxes have each a space of 6 ft. between the tops of their two mirrors; and they are massed together over a space of 5000 sq. ft. When the mirrors are included, the total heat-catching area is about 10,300 sq. ft. This area is made up of twenty-six rows of boxes, each row containing twenty-two single units. The boxes are mounted on trestles, which raise them thirty inches above the ground, and enable them to be inclined so as to receive the utmost possible sun-power. The steam-pipes from the various boxes are connected together, so that they empty into a large pipe, eight inches in diameter, which conveys the steam to the engine. The engine is a reciprocating steam-engine of a new type, and attached to it is an ordinary condenser plant. This turns the used steam into water, and pumps it back into the boxes. Very little water appears to be lost; and this is a point of great importance, as the sun-engine can only be used with distilled water. Were fresh water used, corrosion would soon be set up. Now, however, the boxes have been examined after months of work, and it has been found that there is no corrosion whatever.

A sun-engine working in the tropics, where the weather is always fairly bright, and where coal is dear, will produce more cheaply a given amount of power than a steam-engine could produce in the same place. Twenty degrees on either side of the equator seem at present to be the region in which the sun-engine can be worked at a profit. The whole question turns on the question of fuel; and there can be no doubt that there is a large space on the earth where the sun-engine can be used with advantage. By a miracle of human ingenuity, the burning wastes of Egypt have suddenly been transformed into sources of natural power where the sun is harnessed and made to do whatever kind of work man needs. Perhaps, in a few years, the barren stretches of Mesopotamia, over which the wild Bedouin hungrily roams, will be changed into a vast, fruitful, and quiet garden of peace.


SUN-POWER PLANT PUMPING THREE THOUSAND GALLONS OF WATER A MINUTE 33 FEET HIGH

THE GRIMSBY STEAM TRAWLERS THAT SWEEP ALONG THE OCEAN BED



A FLEET OF STEAM TRAWLERS LYING IN THE GREAT DOCKS AT GRIMSBY, TWO OF WHICH ARE ENTIRELY GIVEN UP TO THE FISHING INDUSTRY

THE HARVEST OF THE SEA

How the Bottom of the Sea is Scraped and Its Waters Sifted for Man's Fish Diet

THE INDUSTRIAL BASIS OF SEA POWER

The sea has so frequently been considered a dreary waste of waters that it is difficult for the ordinary man—be he landsman or seaman—to realise its immense productiveness. The unremitting round of toil for the husbandman, supplemented by the experience of generations, enables him to till and sow and tend, and finally to reap a hard-won harvest from the land, but the seas which surround these islands have been harvested for generations by energetic fishermen whose one aim has been to take *from* the waters. All harvest and no seed-time has been the rule with those who have drawn upon the resources of the sea. When, in the inspiring age of Huxley, attention was first drawn to the necessity for a scientific knowledge of our marine resources, the ignorance of the man in the street upon the subject was perhaps little less wide of the mark than the pseudo-knowledge—more misleading than the darkest ignorance—of the man in the boat. It is no exaggeration to say that practically all the fishermen knew about fish was how to catch them.

But in spite of his educational limitations the average fishing skipper is master of a wonderful art. He has learnt to read the warnings of sea and sky without the aid of a weather-glass, and, most wonderful of all, he knows the sea-floor of the extensive fishing-grounds over which he works, the depth to a fathom and the nature of the bottom, as a keeper knows his game coverts on the land. He can tell the best place for finding fish at different seasons and in various conditions of weather, besides being able to handle his craft so as to ride in safety through the heaviest gale or "tow his gear" in the lightest summer breeze.

If, however, the stock-breeder knew as little about the ways and wants of the cattle he rears as the fisherman knows about the fish he daily seeks and brings to market, he would soon be overwhelmed by disaster. That no such misfortune comes to the fisherman is entirely due to the bountifulness of the harvest of the sea—a compensation for the arduous work of reaping it.

From the pursuit of the herring alone our deep-sea fisheries have extended, by other methods and for other species, till at the present day Great Britain has reached an unapproached predominance in all branches of sea fishery. This is largely due to our geographical command of the North Sea, with its vast stretches of sandy bottom rich in food material for fishes.

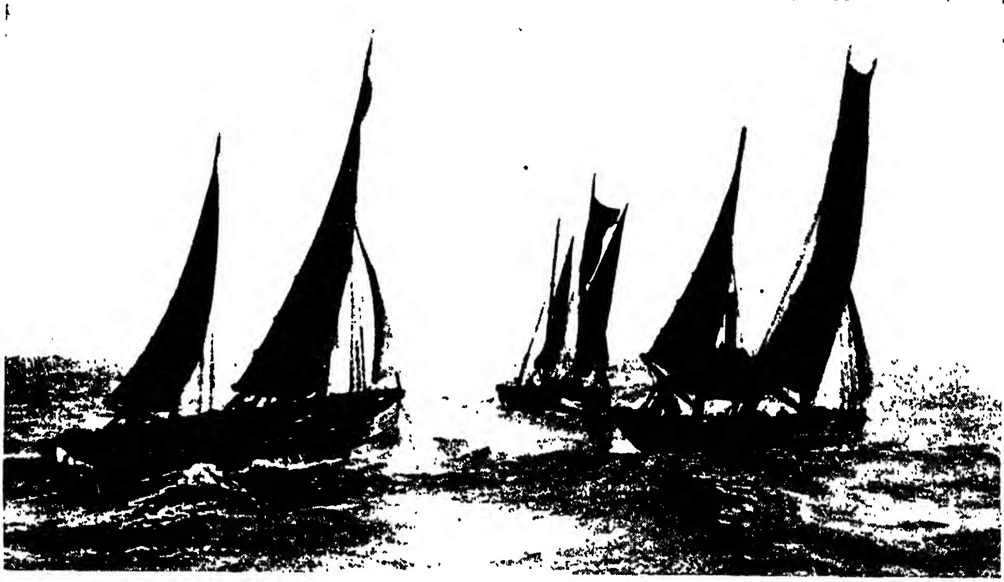
The two great divisions of the industry in which net gear is employed are trawling and drifting. The modern trawler is a powerful steamer, capable of going through any weather, of steaming between three and four thousand miles, and bringing back a hundred tons of fish within three weeks of leaving port. The drift fishery is relatively a passive pursuit by means of which fish such as herrings, mackerel, and pilchards are taken after they have considerately collected in millions, at certain seasons, within well-defined areas.

The North Sea sailing smacks of the middle of the nineteenth century were staunch, picturesque, and fearlessly handled, but modern conditions of markets and railways demanded more than they could accomplish. First, steamships—"cutters"—were requisitioned to take the fish from the deep-sea fleet to market. Then steam was used to haul the huge and ever-increasing net. And, finally, the modern steam trawler has been evolved, and the petrol-motor craft, the latter being now in the stage of lusty infancy. Modern methods of refrigeration and the use of ice have played an equally important part in widening the sphere of fishing operations. The

greatest stimulus, however, has been the depletion of the nearer grounds, and sheer necessity has done a great deal to bring about a condition of things under which we may see cod from Iceland and plaice from the Barent's Sea flanked by hake caught off Morocco, with haddock from the Dogger, conger from the Eddystone, soles from the Bristol Channel, herring from the Shetlands, and mackerel from the North of Ireland, all on the same fishmonger's slab in Birmingham or Leicester.

Fish caught by the trawl exceed to-day, in quantity, variety of species, and value, the fish caught in all other ways. The trawl may be described as a large bag of netting drawn by a moving vessel along the sea-bottom. The net has the shape of a somewhat flattened cone, tapering away from the mouth, its widest part to the extremity, which is always spoken of by fishermen as the "cod end." The trawl has been known from early days, and employed in various parts of the world. There are two types now in general use by European fishermen, distinguished by different methods of keeping open the mouth of the net.

The earlier form, and the one now used by practically all our sailing trawlers, is the beam-trawl. In this the upper edge of the trawl mouth is attached to a heavy beam, usually of oak, raised from the bottom on a pair of iron "trawl-heads," which somewhat resemble very short sleigh-runners, and act in a similar manner, as the trawl is towed along the sea-bottom. The lower part of the mouth of the net is attached to a thick "ground-rope" or "foot-rope," which is frequently weighted by the addition of pieces of heavy chain, so that it may the more thoroughly drag along the sea bottom and so secure those members of the flat-fish family that are wont to lie buried in the sand. The length of the beam, and therefore the width of the mouth of the net, as used by the first-class sailing trawlers, or "smacks," is usually about forty feet; and the height of the trawl-heads, and hence of the net mouth, is about four feet. Two strong ropes, the "bridles," are shackled to each trawl-head, and these are attached to a further rope, the "warp," which acts as the towing-line. The warp is generally passed over the rail on the port side of the vessel. The net is hauled up by means of a capstan, which in former times was worked by hand labour, but first-class smacks now carry a small "donkey" engine for the purpose. Smaller vessels use correspondingly smaller trawls, the smallest in use being shrimp-trawls of six to eight feet in width.



DEEP-SEA TRAWLERS BELONGING TO THE LOWESTOFT FLEET

The most modern form of trawl net is the otter-trawl. The general shape of it is quite similar to the beam-trawl, but the mouth is kept open by two large "boards" which are attached to each side of the net and shackled on to the warps of the towing-gear in such a manner that they "sheer" apart when drawn through the water in a way that is perhaps best described as similar to the

flying of a kite. The most obvious advantage of this arrangement over the beam-trawl is in the increased size of net which it renders possible. The width of the older type of trawl is limited to about 40 to 45 feet by the necessity of having a beam that can be carried along the rail of the bulwarks when hauled inboard. Neither is an excessive height of the beam-trawl "heads" practicable. With the otter-trawl, the size of the net can be much greater, the only consideration being that of the power needed to tow and haul it; and the head-line, instead of being horizontal, extends upward in the form of a bow, and so the net fishes higher in the water than does the beam-trawl. When stowed inboard, the otter-boards are far less cumbersome than the unwieldy beam and "heads," although the net—as used by the steam trawlers of Grimsby, Hull, or Fleetwood—may have a spread of head-line as long as 120 feet. This trawl is used nowadays by all steam trawlers, and by a few small sailing smacks, while practically all smacksmen keep to the more manageable beam-gear.

By far the most important food-fishes caught in the trawl belong to the flat-fish family, including the plaice, dab, sole, turbot, and brill; or to the cod family, which also includes haddock, whiting, hake, and ling. These kinds of fishes are especially liable to capture by the trawl, because of their bottom-haunting habits.

The two old ports of Brixham and Barking compete for the honour of having been the first home of the trawling industry. Whatever the Thames port may or may not have had to do with the origin of the trawl fishery, the men of Devon have been the pioneers and discoverers of practically all the English trawling-grounds.

In the early part of the nineteenth century, Brixham men had ventured eastward from their own fishing-grounds as far as Rye in their small cutter-rigged craft. Then, with larger boats, they rounded the Foreland and commenced the trawling exploitation of the North Sea. Harwich, Lowestoft, and Yarmouth were "discovered" successively as suitable ports at which to land their catches, and many Brixham men settled permanently at these places, where the native fishermen learnt their methods and emulated them with varying degrees of success. Lowestoft has made especially noteworthy headway as a trawling port for sailing vessels, and to-day the Lowestoft smacks are at least the equals of the famous Brixham boats in seaworthiness, in trimness, and in fishing power.

A TYPICAL STEAM TRAWLER OF THE NORTH SEA

The founding of the trawling industry at Hull in the northerly expansion of the exploitation of the North Sea was the result of a happy accident. In those days the smacks used to work in fleets on a particular ground under direction by a code of signals of an "admiral." On one occasion, between 1830 and 1840, a fleet fishing in the Dogger region was scattered by a gale, and one

skipper found himself widely separated from the rest of the fleet. On sounding, he found that the water was of unwonted depth for that part of the North Sea. He shot his trawl, and on hauling found it literally full of fine soles. The news of the great catch soon leaked out, and the somewhat limited depression to the south of the Dogger Bank, thus luckily hit upon, proved a veritable treasure mine to the fishermen who flocked there. It was appropriately named the Silver Pit.

Afterwards it transpired that this discovery was made at a very favourable time —in the depth of a hard winter, when soles congregate in unusual abundance in the deeps. Subsequent severe winters have afforded fine catches in the Silver Pit, but never one equal to the draught that marked the discovery of the ground.

Sufficient stimulus, however, was afforded to the trawling pursuit off the Yorkshire coast to cause the industry to be started at Hull, and this was soon followed by the rise of Grimsby, which has an obvious advantage over the Yorkshire port in being several miles nearer the open sea. This was the time of large smacks that sailed from Hull, Grimsby, Yarmouth, Lowestoft, and from distant Brixham, and fished in "fleets" on whichever ground in the North Sea appeared most advantageous to the "admiral," whose lead was followed in towing the gear, as well as in trimming and reefing sails. The smacks comprising the fleet would stay out for as long as three months, sending their fish to port in a swift-sailing cutter. When steamers afterwards came to be used, the old name was retained, and to this day the fish-carriers are frequently spoken of as "cutters." The "fleeting" system is still practised by certain trawling companies, and the fish is brought by steamer directly from the fishing-ground to Billingsgate Market. The work of transhipping from the trawler to the carrier by means of the trawler's small boat is a hazardous proceeding when carried on—as it often is—in half a gale.

About 1880, steamboats began to be used for beam-trawling, and from that time Grimsby and Hull developed with great rapidity. Gradually the steam trawlers displaced the old smacks from the more distant fishing-grounds of the North Sea, until at the present day a sailing trawler is practically never found as far north as the Dogger Bank. Lowestoft smacks still tow their gear, however, over almost every part of the North Sea between the Lincolnshire coast and the Straits of Dover, and extend as far eastward as the Dutch coastal shallows. Lowestoft is the one important fisher port on the North Sea which has kept almost exclusively to the sailing trawler. This is not due to lack of enterprise on the part of the Suffolk men, but rather to their special geographical position.

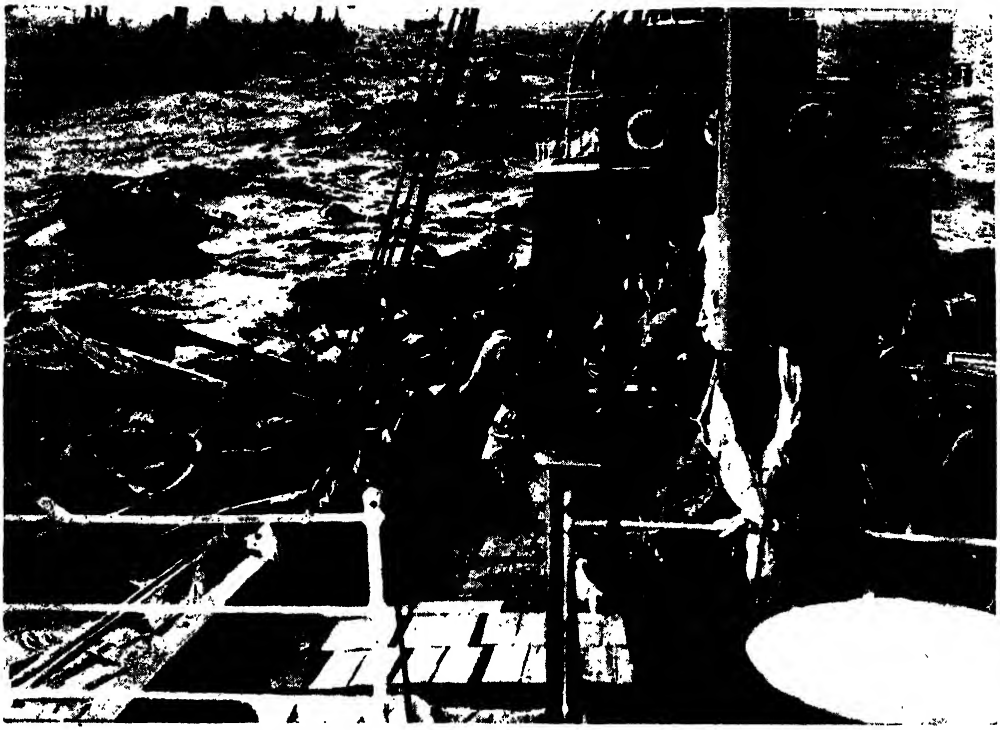
SHOOTING THE TRAWL AT NIGHT

Brixham is the only other port which has maintained the old-fashioned vessels in substantial numbers, and with as much, if not more, of the old-time pride of paint and polish and well-tarred rigging. With the exception of those who chose to settle permanently at Hull, Grimsby, or Lowestoft and lead in the building up of the fishing industry at these newer centres, the Brixham men of recent years have deserted the somewhat depleted North Sea, and pushed forward their pioneering exploits in the western waters. Rich fishing-grounds in Mount's Bay, Bristol Channel, and Cardigan Bay have, in turn, been "discovered" by their efforts.

It was the adoption of the otter-trawl which brought steam trawlers to their present predominance, whereby for the

THE NET-SWEPT HAUNTS OF THE SEA-FISH

THIS MAP SHOWS WHERE, AROUND THE BRITISH ISLANDS, FISH ABOUND, AND ATTRACT TO THEIR LIVING HARVEST BRITISH VESSELS CARRYING MORE THAN 100 000 EXPERT FISHERMEN



TRANSFERRING THE BOXES OF FISH FROM TRAWLER TO CUTTER

year 1908 7,700,000 cwt. out of the total landings of 8,700,000 cwt. were caught by these vessels. The otter-trawl was really a re-invention. It appears to have been known before the introduction of steam trawling, but was apparently regarded as too fanciful for professional consideration, and its use was confined to amateur yachtsmen who found the gear more stowable and less unsightly than a beam-trawl. When adopted by steamers the size of net and boards was greatly increased, and they are still increasing. The boards of the present-day steam trawler are massive, iron-bound structures, appropriately termed "doors" by the fishermen. The head-line of the net has a spread of 120 feet.

Although superior in catching power, the otter-trawl was for some time unable to compete with the beam-trawl on rough, uneven ground, but eventually the ingenuity of the steamer man rose superior to these obstacles. For working the "roughs," the modern steam-trawler has converted his ground-rope into a sort of gigantic string of beads, each bead consisting of a large oak "bobbin." These serve as rollers, and roll over such obstacles as submerged boulders which formerly broke the ground-rope or passed through the cod-end of the trawl, followed of course by the greater part of the imprisoned fishes.

The sandy shallows of the southern North Sea, rich in various forms of invertebrate fish-food, afford a most favourable habitat for abundant fish life, and an almost ideal trawling-ground. Before the introduction of steam fishing the energetic trawling of the fleets of smacks had resulted in appreciable diminution of the original stocks. Forty years ago the line-fishermen cried out against the iniquitous beam-trawl which robbed them of their means of livelihood. Duly sobered down, the fact would appear that big catches by line-fishing became fewer and more difficult to make. Nowadays, the beam-trawling smacksmen condemn the otter-trawl as a menace to the industry. Depletion of certain fish stocks in the North Sea has certainly taken place to a considerable extent, but nevertheless in 1907, out of a total quantity of just over 9,000,000 cwt. of deeper-swimming fish caught by trawls and lines and landed in England, over 4,350,000 cwt. were caught in the North Sea.

The yield of the North Sea grounds soon became too little to satisfy the more enterprising spirits of Grimsby and Hull, and

LANDING A SHIPLOAD OF MACKEREL AT LOWESTOFT MARKET

with vessels of greater power and coal-carrying capacity, and with increasing employment of ice, the field of trawling operations has become rapidly extended. The expansion was first to the northward. The Faröe Banks, where large shoals of cod, haddock, and halibut had for long been a source of profit to " liners," were exploited. But the greatest impetus was given to steam-trawling when the practically virgin grounds off Iceland were discovered in 1892, where plaice, cod, and haddock were found in great abundance.

In the summer of 1905 a Hull skipper, with a bent for exploration, deserted the Iceland grounds, pushed eastward beyond North Cape, and made trial hauls off the entrance to the White Sea. There he came upon immense quantities of fine plaice, and returned to port with a heavy catch. His enterprise was copied—in some cases with great success, in others with failure to make even a moderate catch. Now, failure after steaming 1700 miles is a disaster not to be lightly risked, and, therefore, for a year or two, the White Sea fishery, as it is inaccurately called, was pursued only by a very few of the most superior trawlers of Hull.

Although the richest fishing-grounds lie to the north this is not the sole trend of fishery expansion. The Atlantic trawl fisheries are of increasing importance. Off the West Coast of Scotland, as far as the distant island of Rockall, where cod, haddock, and halibut abound, to the west and south-west of Ireland, the Bay of Biscay, off Portugal, and as far south as the coast of Morocco, British steam trawlers may be found towing their gear up to a depth of 200 fathoms. On these more southern grounds such species as the hake, bream, and megrim largely replace the cod, haddock, plaice, and halibut which are characteristic of the more northern regions. Off Portugal a new fishery for the ever more valuable sole has been developed.

Modern British fishery is indeed a story of the triumph of the trawl, but there is much to be said for the old-fashioned " liner," as those will heartily agree who have tasted the fresh, line-caught haddock of the East Coast of Scotland, or the whiting landed by the " hookers " of Plymouth, and compared them with trawled specimens of the same species. The huge bag constituted by a trawl sweeps over the bottom, and " all is fish that comes to the net "—large and small, sickly or sound, fasting or full. It is a question of quantity *versus* quality,

THE TRAWL-NET BRINGS ITS HARVEST HOME

A TRAWL-NET FULL OF COD MULLET SOLES AND OTHER LARGE FISHES

A MARVELLOUS CATCH AT A FISHERY

EMPTYING THE TRAWL-NET ABOARD THE STEAMER, THE COD END BEING STILL FULL

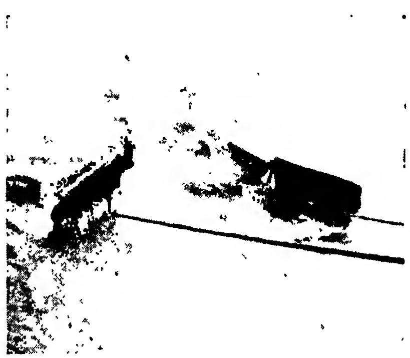
THE NEVER-FAILING HARVEST OF THE NORTH SEA

EARLY MORNING AT THE FISH MARKET AT GRIMSBY, THE LARGEST FISHING PORT IN THE WORLD

and, of course, in this age quantity wins, and the sphere of influence of the "liners" is getting rapidly less.

The species which may be caught on lines include practically all that may be caught in the trawl. A notable exception is the sole, a very valuable trawl fish, which, from its somewhat special diet of small marine worms, is only exceptionally caught on lines. One working advantage which "liners" have over trawlers is that they can work their lines over the roughest of rocky bottoms which would spell ruin to a trawl even with the bobbin-fitted foot-rope of the Hull and Grimsby men. Therefore rock-haunting species—the most important of which is the conger—are caught for the most part on lines. A trawler only expects to get appreciable quantities of such forms as conger and pollack soon after heavy storms have caused them for a time to quit their rocky habitat.

Perhaps the simplest form of line-fishing practised by professional fishermen is the "hand-lining" or "hooking" for whiting which is carried on off Plymouth and various other places round the coast where these fish occur in sufficient quantities. The Plymouth boats which follow this fishing are small cutter or "dandy" rigged vessels of about 24-ft. keel. They vary their mode of fishing according to the season.



OTTER-BOARDS ENTERING THE SEA

Whiting catching is at its best from about April to October. These boats usually carry a crew of three. Their fishing-ground, which may be six to ten miles out of port, is reached in the early evening. They fish all through the night, lying at anchor and heaving in the Channel swell in a way which severely tries the stability of the unseasoned, be they landsmen or sailors. All three hands work at the lines, two lines to each man, and a line carries five or six hooks baited with squid or herring, and is weighted with a lead that varies in size according to the run of the tide.

Besides whiting, such species as pollack, pout, dogfish, conger, skate, and occasionally one or two turbot—worth all the rest of the catch together—may be taken. About six dozen whiting represent a fair night's work. This mode of fishing may have an amateurish complexion and appear tame compared with deep sea trawling, but it is strenuous and hazardous enough. The boats afford the minimum of shelter in a small "cuddy" in the bows, and the night's exposure is only varied by continual hauling of several fathoms of dripping line. In late summer and autumn the whiting come at night to within a few fathoms of the surface, and are caught by a shorter line instead of by the usual bottom-fishing. This style of fishing is most successful when there is a moon, and hence is known as "moon-lighting." The whiting rise to the pursuit of the young fish fry, which are very numerous at this time of the year, and rise nearer to the surface at night, while in daylight they keep for the most part to the deeper layers.

The same South Coast boats which go whiting catching in the summer are usually employed in the early months of the year at the long-line or "boulter" fishing. The "boulter" is a length of stout line which may measure from one to three miles, carrying baited hooks attached to smaller lines or "snoods" at intervals of a few feet. The hooks are baited with pieces of squid, herring, pilchard, or mackerel, and the snoods attached to the "boulter."

"Shooting" the "boulter" begins at about midnight. The end of the line is anchored and buoyed, and then the line is paid out as the boat drops away with the tide. Hauling usually begins immediately after the whole length is paid out. Off the South-West coast conger are the species taken in greatest abundance, and the taking inboard of several six-footers is quite a sporting event, although hardly so thrilling as it has sometimes been represented.

All round the English coast from Berwick to Maryport, and to an even greater extent round the Scottish coasts, this kind of fishery is carried on in open or half-open boats, which may go as much as thirty miles or more from port, and sometimes stay out two or three days. The fish taken include haddock, cod, whiting, plaice, and turbot as the principal kinds.

A certain number of steam liners work the Faröe, Iceland, and Rockall grounds for cod, haddock, and halibut. It is the last-named species that affords them

their chief asset, the halibut being the only important food-fish which is caught in greater quantity by liners than by trawlers. These gigantic flat-fish are kept alive in "wells," out of which they are hauled by ropes passed round the tail. The waters off Iceland used to afford great quantities of line-caught halibut, but of late years the quantity has materially diminished.

The objects of the trawl and line fisheries are those species which live and feed on or near the sea-bottom. The other important class of fish, known as "pelagic" fish, includes the herring, pilchard, sprat, and anchovy—and the mackerel. These swift-swimming and relatively small fishes have the convenient habit—from the fisherman's standpoint—of moving at certain times in vast shoals. The nets used for their capture are merely rectangular pieces of netting of suitable mesh which are suspended perpendicularly in the water. The fish swim into the obstacle before seeing it, and are enmeshed by the gills or first dorsal-fin. Naturally the visibility of the net is a matter of some importance, and therefore the most successful fishing is carried on in darkness. In the French sardine fishery, carried on at sunrise and sunset, the plan of dying the drift-nets a bluish-green colour is adopted.

The greatest drift-net fishery in the world is the British herring fishery in the North Sea, in which nearly a thousand first-class fishing boats from English ports alone are engaged. The now-exploded notion that herrings invade British waters in a vast army coming from the northern seas and gradually working its way southward was based upon the fact that the earliest North Sea fishery began off the Shetlands about May, and then throughout the summer and autumn months the herring appeared successively to the southward. Immediately after the shoals "take off" from the Shetlands the turn of the Moray Firth ports comes. August sees the shoals off the Yorkshire coast when Scarborough, Whitby, and the Tyneside fishing ports, and later Grimsby, reap their share of the silvery harvest. The last and biggest fishery of all is the East Anglian autumn fishery when Yarmouth and Lowestoft have their harbours crowded with drifters, and the odour of herring greets one everywhere

FISH HUNG UP TO DRY—A SCENE IN THE LOFODEN ISLANDS, OFF NORWAY

The problem of the movements of herrings is still by no means completely solved, but recent investigations go to show that local races exist which are characterised by minute anatomical differences, and by having different spawning seasons. The fisherman's broad classification is into winter herring and summer herring, according to the time at which they spawn. It is their habit of congregating into shoals for breeding purposes which yields the best opportunity for their capture in such vast quantities. They appear to choose those grounds where the bottom is rough and pebbly or shelly, as this affords the best repository for their spawn. The shoals have practically without exception visited the same neighbourhoods every season for hundreds of years.

In former years the herring harvest was a comparatively local affair to the various fishing communities around the coasts. But now commercial enterprise and the use of steam have wrought a change. The modern drifters are capable of going anywhere, and they follow up the fishing from the Shetlands area in May to the Norfolk coast at Christmas, so that East Anglians work off the Scottish coasts and land at Scottish ports in summer, and the Scotch fishermen return the compliment in autumn. The seasonal migrations of the boats are accompanied by migrations of merchants and curers, with their hosts of employees engaged for the work of cleaning and packing. The latter consist almost exclusively of Scots "lassies" of all ages, from sixteen to sixty, who constitute a picturesque addition to the population of the East Coast herring ports every season.

The method of fishing is the same for the powerful steamer of Aberdeen, Yarmouth, or Lowestoft, with its three-mile long train of nets, as for the small open boat of the villager. The fleet or train of nets is shot at dusk from the bow of the vessel so as to be carried away in a line by the tide, thus forming a long wall of netting hanging perpendicularly in the water. The upper edge is suspended from floats made of cork or of bladders. The depth of the head-line varies, but it is commonly worked at about four fathoms. After midnight is usually the best time for the fish to "strike," which they sometimes do with such a simultaneous rush that the movement can be felt on board. Too heavy a catch is not appreciated by fishermen, especially in rough weather, for it frequently involves loss of nets, borne to the bottom by weight of fish, and torn away from the warp. The quickness with which the fish are unmeshed as the long length of net is gathered in, and the skill shown in stowing the nets away without the inextricable confusion that seems to the unprofessional observer quite inevitable, are things that must be seen to be appreciated. Then follows the race for the market, and the landing of the catch, which, in the case of the large boats, may amount to about thirty-five tons of fish.

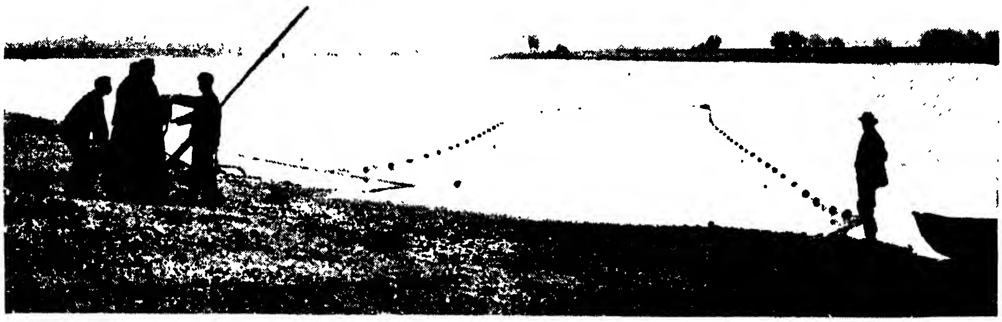
SCOTTISH LASSIES CLEANING FISH AT GRIMSBY

The wonderful thing about the North Sea herring fishery is that in spite of a greatly increased intensity of fishing the shoals appear to be as large as ever, or even more so—a very different state of affairs from that which exists in the trawling industry. It has been suggested that augmented herring supplies have resulted from the decimation of haddock by the trawlers, haddock being voracious devourers of herring spawn. In 1907 over 4,000,000 cwt. of herring, marketed for over £1,000,000, were landed on the East Coast of England, the catches landed in the remaining part of

England and Wales amounting to less than 250,000 cwt.

The mackerel is the second important species taken by drift-nets, a somewhat larger mesh being used than for herrings, while the depth at which they are fished varies. The most important mackerel fishing is pursued to the west of the Scilly Isles in the spring, and is shared by the East Anglians as well as the West Country boats. The fishermen, taught by experience, know from the appearance of the sea where mackerel are likely to be present or not. Sometimes they are present in such quantities that the market is glutted, and they can only be sold as manure.

Pilchards, too, are caught by drift-nets, but with a somewhat smaller mesh than the herring-nets. This fishery affords a valuable spell of employment for the luggers of Penzance and the neighbouring Cornish ports between the spring mackerel and the winter herring season of the West.



FISHING FOR SALMON WITH A "SEINE" NET AT KINFAUNS, PERTHSHIRE

If the various kind of fishing nets were described in the order of their evolution the "seine" would take precedence of the trawl and drift nets. It was with gear of this type that the Apostles worked on the Sea of Galilee.

The seine has various modifications, but in its simplest form consists of a long piece of netting deepest in the middle and tapering towards each end, suspended in the water by means of corks along the head-line and lead weights along the foot-rope. The method of working it is to move one end by means of a rowing-boat in a circular direction so as to surround a number of fish, drawing the ends together, and finally securing the captives by dragging them on the beach or scooping them out of the net into a boat. The seine is commonly used for the capture of mackerel on the Devon and Cornish coasts, and for sprats at Torquay and the ports along the Thames Estuary, and, according to local conditions, such diverse species as the salmon and the plaice may be taken in this way.

An important fixed net of quite a different type is the stow-net used by the spratters and whitebaiters of the Thames Estuary and the Wash. The season of this fishing is from November to February. The net is an enormous bag like a funnel, with a nearly square mouth, 20 feet by 30 feet wide, and tapering after about 90 feet to a diameter of 5 feet by 6 feet, then diminishing to half that size in its remaining length of 90 feet. The tiny fishes are brought into it by the tide, and are driven by pressure of water to the distant far end. Whitebait consists of young sprats and herrings, with an occasional admixture of other fry. The sprat is also taken in seines, and in larger numbers in small-meshed drift-nets. Aldeburgh, in Suffolk, is the centre of the sprat fishery. There the sprat holds the same position as the herring does at Yarmouth.

Among Continental nations the French take the first place as fishers, and they succeed by following their own methods, with steam trawlers and "liners" from Boulogne and Fécamp, and sailing vessels from Dunkirk to Paimpol. The sardine fishery is located in the Bay of Biscay and the Mediterranean. The sardine is simply the young of the pilchard. It is caught at sunrise or sunset in a small-meshed drift-net, dyed a greenish-blue to render it invisible, and the sardines are tempted into the net by handfuls of salted cod's roe thrown on the waters.

Norway has an energetically conducted fishery, particularly off the Lofoden Islands, the annual catch realising more than a

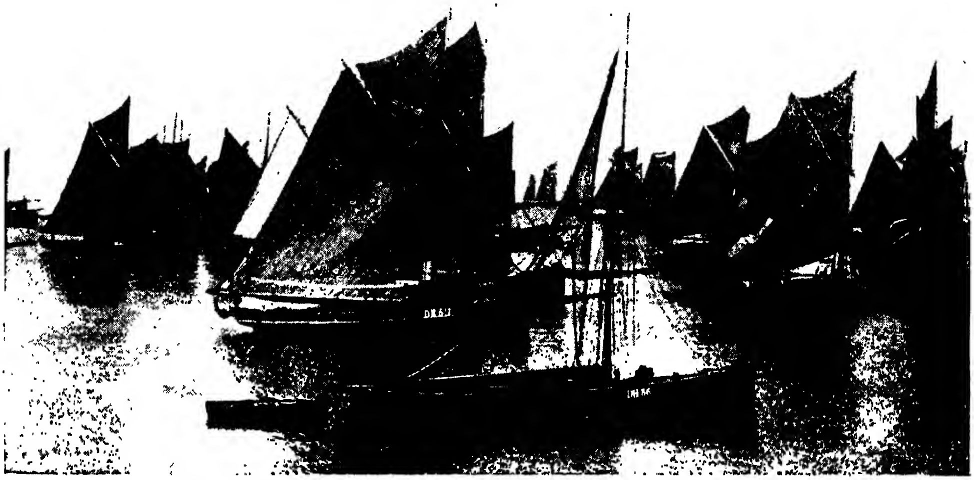
million of money, and the Government gives intelligent assistance through a study of the breeding and migration of the fish. Swedish fisheries are subsidised by the State. Denmark, above all countries, is the nursery-ground of the plaice. The transplantation of plaice to inland salt waters has been successfully carried out. The eel fisheries of Denmark are valuable, and the Danes stand first as students of the life history of this wonderful fish. The Dutch have a herring fishery that employs about six hundred vessels, and is worth nearly a million a year. Their practice is to salt their herrings as they catch them, instead of running for the readiest market. The German fisheries are being developed with determination, largely by the use of steamers. The Mediterranean is not energetically worked even by the French. Fish that are caught there in considerable quantities, such as the tunny and anchovy, shoal close by the land.

Overseas Britain possesses, off Newfoundland and Canada, some of the most valuable fisheries of the world. The cod fishery over the Banks of Newfoundland dates back to 1540. The value of the Canadian Atlantic fisheries is over £5,000,000 a year.

On the Pacific side the sea offers enormous ungathered wealth, as the Canadians are beginning to realise. The industry has not been developed to any considerable extent in Australia, New Zealand, or South Africa, but is receiving attention.

Perhaps the most sensational fishery in the world is the salmon fishery in the estuaries of western North America. The fish press forward to their spawning grounds in millions, and are caught in such numbers that the British Columbian output from the various tinning establishments reaches an annual value of over five million pounds.

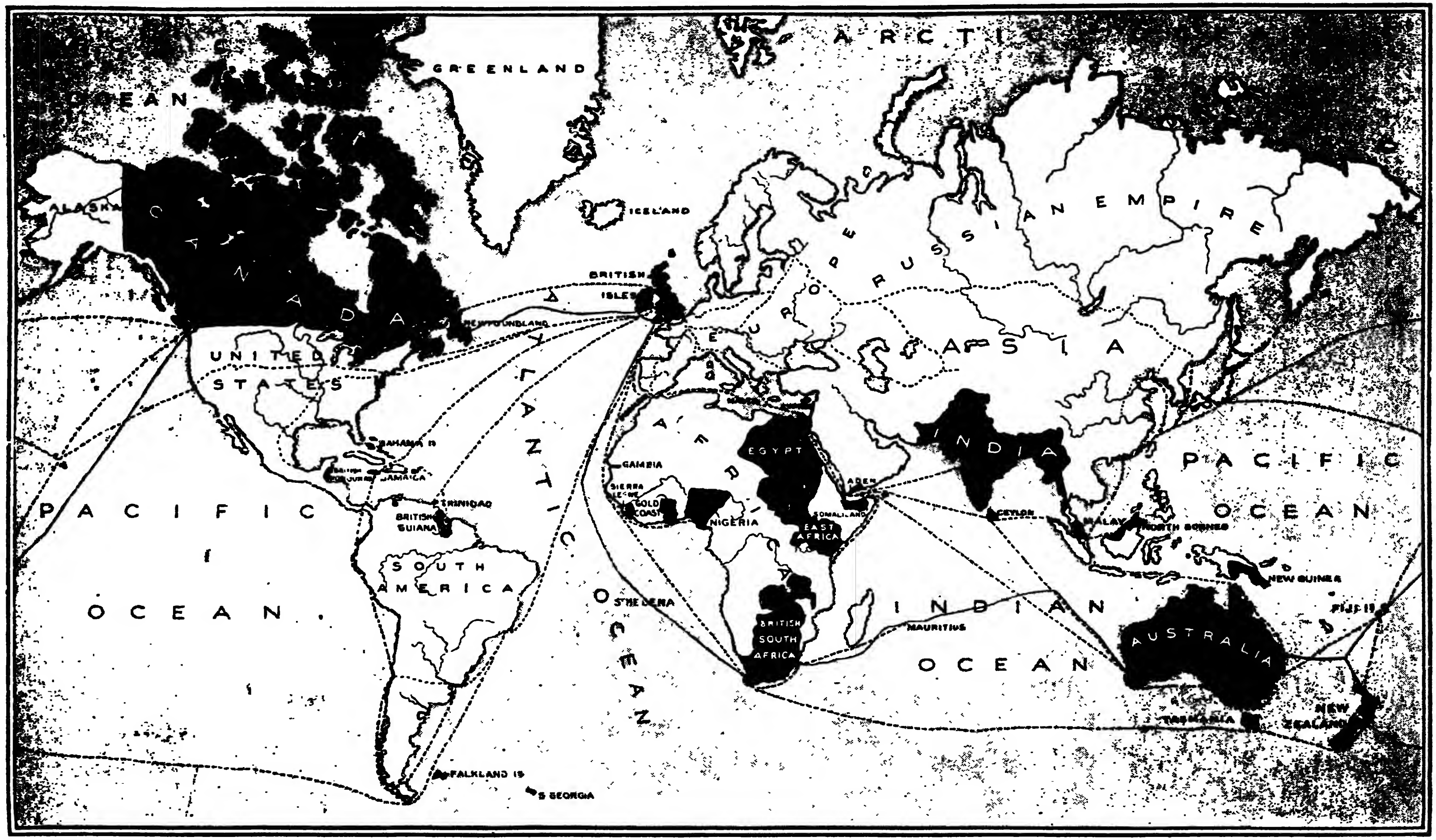
Considering the enormous importance of the British fisheries the Government spends singularly little on their care and development. The amount so spent for the British Islands is less than £46,000 per annum, according to the latest available comparative returns, whereas Canada spent £207,000, the United States £141,000, Germany £27,750, and Norway £20,000, or within £2000 of what was spent on the fisheries of England and Wales. About 110,000 persons are engaged in the British industry, over 73,000 being constant workers on the boats.



FISHING-SMACKS OFF BRIXHAM, THE PIONEER PORT IN THE FISHING INDUSTRY

The total value of fish landed in the United Kingdom from British boats was £11,659,000 in 1910. The number of steam trawlers in the business in 1907 was: British 1615, German 239, French 224, and Dutch 81, the other countries using chiefly smacks. From Grimsby alone over 500 vessels put out, and two of its docks are entirely given over to the fish trade, linking up the fishing fleets, through the railways, with all the great towns of the kingdom. The French fishing trade, which is much more largely inshore than ours, has about half the value of the English trade, and the German and Dutch trade each only about one-tenth.

THE CHIEF HIGHWAYS OF THE COMMERCE OF THE BRITISH EMPIRE



In this map of the world the British possessions are shown dark. The principal cables are shown in black lines, and the principal trade routes in dotted lines.

AN EMPIRE'S BUSINESS

A Rapid Survey of the Commercial Relations of More Than One Quarter of the Entire World

THE CENTRE OF GRAVITY OF THE EMPIRE

To consider the trade of the British Empire is to survey the dealings for gain of one-fourth of the population of the entire world. In the fourth chapter of this work we dealt with the resources and chief productions of the great British Dominions, which cover more than one-fifth of all the world's land. We now come to an examination of the commercial transactions of the hundreds of millions of people under the British flag—people whose racial origins, habits, customs, and religions are as varied as their material productions.

It is impossible to understand the trade of the Empire without closely analysing the distribution of the Empire's population. Although there are over four hundred million people who own allegiance to Britain, by far the greater part of the Empire's white population is still to be found in the United Kingdom. All the whites in the Empire put together, of all races, including French-Canadians, Boers, and so on, number no more than sixty millions, and of these forty-five millions are the inhabitants of the British Isles. That is to say, the great self-governing dominions, together with India, the Crown Colonies, the British Protectorates, etc., contain no more than about *fifteen millions of whites, or about twice the population of Greater London.*

It is truly a wonderful thing, this governance by a comparative handful of white people of territories which constitute a world in themselves, and contain over four hundred million inhabitants, The British Dominions obviously have room for tens of millions of white men, and one of the most interesting problems of the future is how they are to gain those millions of British race without unduly denuding the Mother Country. The gravity and importance of this Imperial problem are accentuated by the deplorable fall in the British birth-rate. It would be travelling beyond the province of this chapter to discuss the matter in detail, but no one who has regard for the future of the Empire, or indeed for the future of mankind, can view without some degree of anxiety and apprehension the fall in the rate of increase of the British and other white peoples. If a world of over 1600 million people is to be led in the future by its most gifted races, it is manifestly one primary duty of those races to be fruitful and multiply. The problem is thus one of world-wide character, but we shall do well to remember that it has a special relation to the maintenance of the integrity of the British Empire.

The deeply interesting facts on this head are given in near approximation in the table which appears on page 1114, which gives an estimate of the population of the British Empire in 1911. The white population is distinguished from the remainder with as much accuracy as is possible.

We see the United Kingdom standing out, not merely as the nominal head and front of the Empire, but as its real leader by virtue of the possession of three-fourths of its white people. It is clear that the centre of gravity of the British Empire is still in the United Kingdom. The table next analyses the population of the self-governing dominions, and we see that they contain as nearly as possible fourteen millions of whites out of a total population of nineteen millions.

Canada and Newfoundland are almost entirely peopled by white men. The majority of them are of British descent, but about a million and three-quarters are French-Canadians, and there are about a million more compounded of all the races of Europe. Australia has but four and a half million people (as many as 1,200,000 of whom are actually crowded into two towns, Sydney and Melbourne), and she is

beginning to realise that, if she is to remain a white man's country, it is absolutely necessary for her to encourage immigration, and not to discourage it as she has in the past. New Zealand has as yet but a million people, including a few Maoris, or little more than the population of Glasgow. South Africa has far more blacks than whites, and is badly in need of population, which she can scarcely gain in great numbers unless she finds it possible to develop her power supplies. The total population of the self-governing dominions—nineteen millions—is little more than that of the tiny empire of. Portugal, a fact which illustrates what tremendous possibilities of industry and trade are latent in them awaiting the arrival of more white men.

The remainder of the Empire contains very few white men, even including the British garrisons, but it contains by far the greater part of the Empire's people. The population of India is shown to be 315 millions by the census of March, 1911, and 35 millions is a conservative estimate of the aggregate population of the West Indian, African, South American, Malayan, and other territories.

The grand total of the Empire's population is 416 millions, of whom, as nearly as possible, *one person in seven is a white.*

With the foregoing facts before us, we learn without surprise that, when it comes to measuring the commerce of the British Empire, the trade of the United Kingdom forms by far the greater part. The latest year for which we are able to compare the trade of the United Kingdom with that of the British Empire is 1909. In tha year the British Empire, considered as whole, imported from foreign countrie £656,000,000 worth of imports, and exporte to foreign countries £545,000,000 worth o exports, making a total foreign trade o £1,201,000,000. Comparing this with th trade done by the United Kingdom alon we get the following result.

TRADE OF THE BRITISH EMPIRE AND THE UNITED KINGDOM COMPARED FOR 1909

	BRITISH EMPIRE *Considered as trading with Foreign Nations*	UNITED KINGDOM *Considered as trading with all the world outside it*	UNITED KINGDOM *Considered as trading with Foreign Nations*
	Million £	Million £	Million £
IMPORTS ..	656	625	479
EXPORTS ..	545	470	332
TOTAL ..	1,201	1,095	811

It will be seen from these facts that th United Kingdom counts for far more in th world's commerce than all the rest of th Empire put together. Not that the trade o the Britains over the seas is by any mean inconsiderable; on the contrary, whe considered in the light of their populations the self-governing dominions have alread built up a remarkably great commerce, a considerable part of which is transacted wit the Mother Country. In the following tabl the imports of the chief component parts o the Empire are shown.

THE POPULATION OF THE BRITISH EMPIRE IN 1911, DISTINGUISHING THE WHITE POPULATION FROM THE REMAINDER

	WHITES Of all races	OTHERS	TOTAL
1. **United Kingdom:**	45,000,000	—	45,000,000
2. **Self-Governing Dominions:**			
Canada	6,950,000	200,000	7,150,000
Newfoundland	250,000	—	250,000
Australia	4,400,000	100,000	4,500,000
New Zealand	950,000	50,000	1,000,000
South Africa	1,400,000	4,700,000	6,100,000
Total	13,950,000	5,050,000	19,000,000
3. **Other British Possessions:**			
India	300,000	314,700,000	315,000,000
Rest of the Empire	250,000	34,750,000	35,000,000
Total	550,000	349,450,000	350,000,000
Grand Total	**59,500,000**	**354,500,000**	**414,000,000**

IMPORTS OF THE SELF-GOVERNING DOMINIONS AND INDIA FOR 1909

COUNTRY	FROM ALL THE WORLD		FROM UNITED KINGDOM ONLY	
	Goods	Bullion	Goods	Bullion
	£	£	£	£
Canada	79,300,000	1,200,000	19,700,000	—
Newfoundland	2,300,000	—	500,000	—
Australia	50,200,000	1 000,000	25,800,000	—
New Zealand	14,900,000	800,000	9,200,000	100,000
S. Africa	28,300,000	1,500,000	16,700,000	100,000
India	86,600,000	25,000,000	52,400,000	14,300,000

The extent to which the Oversea Britains can draw their imports from the United Kingdom varies, of course, with their geographical position and their needs. Canada, it will be seen, draws but about one-fourth of her imports of merchandise from the home country, and that in spite of the existence of a tariff preference for British goods. The explanation is twofold. In the first place, the contiguity of the United States, and the great similarity of taste in many goods which obtains in the two countries, make it natural for Canada to trade with her southern neighbour. In the second place, Canada is a considerable purchaser of raw materials of a kind which we do not sell, and which we have to import ourselves. Obviously, Canada cannot get from us such products as cotton and wool and indiarubber, which she needs to carry on her various industries. Similar considerations apply in more or less degree to the other British possessions, but it will be seen that Australia, New Zealand, South Africa, and India draw much longer proportions of their imports from the United Kingdom than Canada does. India is by far the best customer of Britain in the British Empire. Her imports from the United Kingdom are about as great as those of Canada, Australia, and New Zealand put together.

Turning to exports, we get the interesting figures in the table below.

A large proportion of the exports of the self-governing colonies and India is absorbed by the United Kingdom. Canada and Australia each send us about one-half of their total exportations. New Zealand markets almost all her produce in the United Kingdom; South Africa sends us more than three-fourths of her exports. India, however, has to find foreign markets for the larger part of her produce; she sells chiefly raw materials, and although we are large purchasers of materials, a big surplus has to be placed elsewhere.

Australia, New Zealand, South Africa, and India, as large producers of gold and silver, have a considerable commerce in the precious metals. South Africa, it will be seen, exports far more gold than other produce, and does, therefore, literally pay for a large part of her imports with bullion. Almost the whole of the wonderful South African gold output comes to the world's one great gold market, which is London.

There is, of course, a very great general difference between the imports and the exports of these daughter Britains. As a general rule, they are chiefly exporters of foods and raw materials, and chiefly importers of manufactured articles. Canada's imports of £79,300,000 in 1909 consisted as to £44,500,000 of manufactures. In the case of the other Colonies, the proportion of manufactures in the imports was much higher than this. Australia's imports of

EXPORTS OF THE SELF-GOVERNING DOMINIONS AND INDIA FOR 1909

COUNTRY	TO ALL THE WORLD		TO UNITED KINGDOM ONLY	
	Goods	Bullion	Goods	Bullion
	£	£	£	£
Canada	61,400,000	500,000	30,800,000	—
Newfoundland	2,200,000	—	300,000	—
Australia	55,700,000	9,600,000	28,500,000	2,400,000
New Zealand	17,500,000	2,200,000	15,000,000	1,200,000
S. Africa	17,700,000	33,400,000	13,500,000	33,300,000
India	129,200,000	4,300,000	33,000,000	£2,200,000

£50,200,000 in 1909 consisted as to £38,300,000 of manufactures. New Zealand's imports of £14,900,000 were as to £10,500,000 manufactures; South Africa imported £20,400,000 worth of manufactures in a total importation of £28,300,000. Finally, India's importation, valued at £86,600,000, contained £62,200,000 worth of manufactures.

It is in manufactures alone that the United Kingdom is able to compete in Colonial markets, and the following statement will make clear how far she succeeds:

THE UNITED KINGDOM AS SELLER OF MANUFACTURES IN COLONIAL MARKETS

Country	Total Imports of Manufactures	Manufactures Imported from United Kingdom	Manufactures Imported from Foreign Countries
	£	£	£
Canada ..	44,500,000	16,000,000	28,400,000
Newfoundland	1,000,000	400,000	400,000
Australia ..	38,300,000	23,400,000	12,700,000
New Zealand.	10,500,000	8,000,000	1,300,000
South Africa.	20,400,000	14,800,000	4,900,000
India	62,200,000	48,600,000	12,000,000

It will be seen that the aggregates of the last two columns very nearly reach the totals of the first column; that is because the Colonies import very little indeed of manufactured stuff from each other.

It is in Canada that British competition in the sale of manufactures is weakest. The explanation we have already given. When all allowance is made for any possible element of truth there may be in the complaints we have so often heard that the British exporter is not enterprising enough in the Canadian market, it is difficult to see how sellers on this side of the Atlantic can operate in the Canadian market with the local knowledge and expedition which are the natural advantages of the American exporter. With regard to the Commonwealth of Australia, we do very well; two-thirds of the Australian imports of manufactures are derived from the Mother Country. In New Zealand, curiously, we do even better, supplying nearly four-fifths of the Dominion's purchases of manufactures from all the world. The South African record is also excellent, the United Kingdom furnishing over two-thirds of her imported goods. The British trader is also easily supreme in the Indian market, where he supplies over three-fourths of all the manufactures imported. It should be remembered that this is done in perfectly open competition with the world at large, as India has a Free Trade tariff.

We have been speaking of the British trader's competition with the foreign exporter in the Colonial markets. There is another competition to face in the Colonies, however, and that is the growing strength of the Colonial manufacturer, who in the long run will prove to be the chief competitor. In that connection everything depends upon the success with which Colonial power supplies, whether in coal or in water power, are developed. We must expect that some day the New Zealander, if unlikely to survey, as Macaulay imagined, the ruins of Westminster Bridge, will aspire to export woollen goods rather than raw wool. Indeed, although leather is the only manufactured article which appears in the list of principal articles exported by New Zealand, Canada has become a not inconsiderable exporter of manufactured goods.

The Canadian list of exports includes agricultural implements, cotton goods, leather, leather goods, boots and shoes, engines, machinery, sewing-machines, typewriters, ready-made joinery, wood pulp, musical instruments, and many other articles. The import returns of the United Kingdom show that, of articles wholly or mainly manufactured, the United Kingdom imports from British possessions to the value of about £18,000,000 a year. A great part of this, however, consists of crude metals. It will be some time before the British Dominions become considerable exporters of manufactures, for they are rapidly gaining immigrants, and their manufacturing expansion will therefore be devoted chiefly to meeting the growing needs of their home markets.

The part which is being played by the British Empire outside these islands in feeding the United Kingdom's population is a great and growing one. If our population continues to grow, as it must do if Britain is to retain her relative place in the world, the question of food supplies will become increasingly important. Some people imagine that the United Kingdom is overcrowded with people, but it is really difficult to put a practical limit to the possible growth of the British population, if the United Kingdom can succeed in expanding her export trade sufficiently to secure from abroad an abundance of food and raw materials.

The fact that forty-five millions by no means represents the limit of our expansion will be evident when it is stated that the little kingdom of Belgium has a population

of 590 to the square mile, at which rate the 120,000 square miles of the United Kingdom would have a population of nearly 71,000,000, or 26,000,000 more than in 1911.

There is no economic reason why the United Kingdom should not realise such a population, or even a greater population, in practice. She has, of course, her power supplies, which are surpassed by those of few other countries, and she has therefore at command the means of carrying on the work necessary to maintain a larger population. The question of comfortably housing a population even twice as great as that now possessed by the United Kingdom presents no difficulties, given the industry to maintain them. Ninety million people means eighteen million families, and to house eighteen million families, at six families to the acre, would absorb but three million out of the seventy-seven million acres of the United Kingdom.

It may be confidently submitted that, unless coal is dethroned as an industrial power, and therefore as a determinant of population, the United Kingdom can, by gaining imports of natural produce through the exportation of manufactures, become a greater Britain still. And, indeed, it is essential that she should do so if she is to remain the capable, worthy, and efficient head and front of a world-wide Empire. It is consequently a matter of moment to be able to count in the United Kingdom upon the ability of the Britains over the seas, and of new lands which are foreign countries, to supply our home population with foods and materials in exchange for the manufactures with which alone the United Kingdom can pay for such supplies.

The record of recent years shows that British possessions are rapidly improving their position as food suppliers. The following table brings this out clearly.

FOOD IMPORTS OF THE UNITED KINGDOM
The totals include a little tobacco

Year	From Foreign Countries	From British Possessions	Total
	£	£	£
1906..	181,800,000	56,300,000	238,100,000
1907..	185,600,000	61,700,000	247,300,000
1908..	192,500,000	51,700,000	244,200,000
1909.	190.500,000	63.800,000	254,300,000
1910..	186,500,000	71,200,000	257,700,000

While the foreign supplies slightly increased in 1906-1910, the Colonial supplies considerably increased. It is fortunate that British produce has thus multiplied. The great feature of the export food supplies of the world in recent years has been the falling off of the United States as an exporter. If other lands had not been prepared to take up the running, there would have been a very serious increase in the price of food—a much more serious increase than has actually occurred. We have continued to obtain the supplies, without which our population could not exist, by virtue of the development of crops and flocks and herds on foreign soil in South America, and on British soil in our great dominions.

There cannot be too many or too great suppliers for the convenience and safety of the British population in their unique economic position, and if we rejoice that the second column in the table just given exhibits so much increase, we cannot afford to be glad that foreign supplies do not also exhibit the same rate of expansion. It is necessary to our continued existence as a great nation that there should be offering in the world opulent supplies of food not needed by those who grow them, and we are vitally interested in the active development of what are called "new" lands.

Similar considerations apply to our command of the raw materials of industry. We have already seen that British work is so largely done upon foreign products that the cessation of imports of materials would bring nearly all British work to a standstill in a few weeks. The British Empire, unlike the Mother Country, is a great producer of most of the important materials, and plays a great part in furnishing us with the basis of our work. The following figures show the sources of our supplies in the last five years.

RAW MATERIAL IMPORTS OF THE UNITED KINGDOM

Year	From Foreign Countries	From British Possessions	Total
	£	£	£
1906..	147,700,000	63,400,000	211,100,000
1907..	169,600,000	71,600,000	241,200,000
1908..	145,600,000	57,800,000	203,400,000
1909..	155,900,000	64,300,000	220,200,000
1910..	181,100,000	80,000,000	261,100,000

A part of these supplies is re-exported in the merchant trade; hence the imports for home consumption are smaller than these totals.

In this case both foreign and Colonial supplies exhibit a very similar rate of expansion, and it will have been gathered that we have good reason to be glad that it is so. The first sign of decline in British industry would be a fall in the imports of the

raw materials of industry, and no better test can be applied to the progress of our trade than to watch the growth of the raw material imports.

The full economic development and conservation of new lands—and amongst them the British Colonies and Possessions take a high place—is of great moment to our industrial future. The increasing interdependence of the countries of the world is ever deepening our interest in the development of the world at large. The staple trade of a great industrial town in England may be brought almost to a standstill by the failure of produce in a far-off land; the citizen of every country is increasingly becoming a citizen of the world, who has good need to understand the work of the world, and to desire its peaceful and economic conservation.

The growth of new lands affords great opportunity to the British exporter. New lands are new markets, and, as we have already seen, the new land is necessarily a buyer of just those articles which we chiefly have to offer—manufactured goods. The settlement of such places as Canada or Argentina, Australia or Brazil, South Africa or Mexico, means that millions of migrants and prospectors are engaged in redeeming wilds for civilisation, and demanding an ever-increasing stream of tools and implements, rails and locomotives, utensils and furniture, clothing and boots, ploughs and harvesters, locks and fastenings, fencing wire and galvanised iron, and the thousand other appliances and comforts with which the modern settler attacks the prairie and the wilderness. The energy that is spent in building up a town in the prairie is reflected, we may say, in factories and workshops thousands of miles away.

It is not generally realised how prodigious is the potential demand for manufactured goods which exists in the world, and how comparatively small are the existing means for satisfying that demand. There is not the slightest reason to fear that the workshops of such a land as ours need lose custom, if those who work them continue to exert their old-time enterprise. The total output of all the world's industrial plants is merely insignificant as compared with what is needed to raise to a decent standard of comfort and civilisation even the existing inhabitants of the world, to say nothing of the enormously greater number of people that the world will come to contain.

We have so barely touched the fringe of possibilities in this direction that the time may come when the trade statistics of to-day will appear as absurdly small as those of, say, 1850 appear to us now, at the beginning of the twentieth century.

These considerations go to confirm and sustain us in the belief that our country can support by manufacturing industry an enormously larger population.

Among the world's new markets the Britains beyond the seas afford some of the best opportunities of the British trader. We have shown that British exports already play a very large part in the supplies purchased by our Colonists. It is of interest to see what part is played in our aggregate trade by British possessions. The next table shows the sources of all British imports in the last five years.

SOURCES OF UNITED KINGDOM IMPORTS

Total imports, including those afterwards re exported in the merchant trade.

Year	From Foreign Countries	From British Possessions	Total
	£	£	£
1906..	468,000,000	139,900,000	607,900,000
1907..	491,100,000	154,700,000	645,800,000
1908..	464,800,000	128,100,000	592,900,000
1909..	479,500,000	145,200,000	624,700,000
1910..	507,800,000	170,400,000	678,200,000

Such are the sources of the imports without which the United Kingdom could not keep its flag flying, and which it must still increase if it is to grow with the growth of the world. It will be observed that while the increase in both foreign and Colonial imports is satisfactory, the larger gain has been made on the Colonial side; that will not surprise those who reflect that it is a very large share indeed of the rapidly developing new lands of the world which are within the confines of the British Empire. It will help us to realise the growth of the past, and to feel confident as to the growth of the future, if we note how wonderfully the above figures compare with those of bygone years. In 1910 our imports, from within the Empire alone, were greater than our imports from all the world as recently as 1858. Again, in 1910 our total imports were twice as great as at the date of the Franco-German War. It is within the bounds of possibility that the lapse of another generation may see our imports from within the Empire as great as our total imports are now.

Passing to the destination of British exports, we find the following facts for the same period of five years.

DESTINATIONS OF UNITED KINGDOM EXPORTS

Exports of British Goods only.

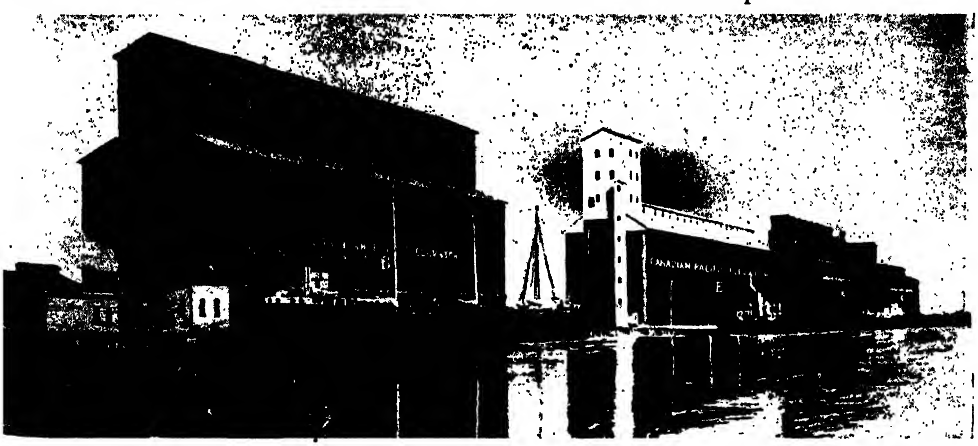
Year	To Foreign Countries	To British Possessions	Total
	£	£	£
1906..	253,600,000	122,000,000	375,600,000
1907..	287,900,000	138,100,000	426,000,000
1908..	250,300,000	126,800,000	377,100,000
1909..	250,900,000	127,200,000	378,100,000
1910..	283,100,000	147,300,000	430,400,000

Here, again, while a considerable growth s exhibited in both our exports to foreign countries and our exports to British possessions, the latter exhibit the greater proportionate gain. In the five years 1906-1910, exports to foreign nations gained £29,500,000 upon £253,600,000; while exports to places within the Empire gained £25,300,000 upon £122,000,000. As time goes on, with the free growth of the self-governing dominions, the exports to British possessions should rise enormously, given the maintenance of our population here.

Again we may note how well the figures of 1910 compare with those of a not remote past. In 1910 the exports of British goods, to British possessions only, were as great as our exports to all the world as recently as 1863. Again, our exports, to foreign countries only, in 1910, were greater than our exports to all the world eight years before —in 1902. Our total exports in 1910 were twice as great as our total exports in 1895, only fifteen years before. These facts illustrate that remarkable acceleration of progress in the twentieth century to which we have already directed the special attention of the reader.

That acceleration may prove to be but a hint of a greater acceleration to come. Man is but just beginning to apply the marvellous powers which have been conferred upon him by scientific investigation. Those who know most of the degree of mastery of Nature which Man already possesses are the most confident that it needs but a full application of scientific knowledge to multiply the products of industry to a degree undreamed of by those who gauge future progress merely by what has happened in the past. To judge by past progress is to predict, it is true, no small degree of future development, but to judge by the light of science is to predict with certainty a brilliant future for mankind.

What we have considered earlier in these pages has shown us how great a part in that brilliant future must be played by the science of distribution, and the facts we have studied above serve to show that the British Empire, under wise governance, may come to be the home of many hundreds of millions of people, serving each other, and exchanging with the world at large, in a measure far transcending its present almost tentative operations. The Commonwealths within its borders are conducting many fruitful experiments, and helping each other by frequent conferences along the path of safety and progress. There are dangers to be avoided, and the chief of them is the decline in the British birth-rate. In that, and in other cognate matters, not commerce alone is concerned, and we realise how full must be the information, how vigilant the care, how wise the statesmanship, of those to whom the leadership of men is entrusted.



SHIPPING WHEAT FROM ONE OF THE ENORMOUS GRANARIES ON THE CANADIAN PACIFIC RAILWAY

DAY AND NIGHT IN A SAVAGE SOCIETY

DAY IN AN AFRICAN VILLAGE WITH SOME APPROACHES TO SOCIAL ORGANISATION

NIGHT ENCAMPMENT IN A SAVAGE COMMUNITY AS OBSERVED BY PAUL DU CHAILLU

The story of early man may be inferred in some measure from the traditional methods still followed by the tribes remaining in the lowest stages of social and economic development.

SOCIETY IN THE MAKING

The Social Forces that Brought Men Together into Clans, Tribes, Nations, and Empires

BRAIN CAPACITY IN MAN, EARLY AND LATE

About a hundred thousand years ago, or, according to some authorities, two hundred thousand years ago, a race of people called the Mousterians were living in scattered families about Europe. The brain capacity of the modern European is about 1550 cubic centimètres; and as Professor Huxley reckoned that the brain capacity of the Mousterians was only 1250 cubic centimètres, it was easy to account for the savage condition of the primitive race of the Old Stone Age. They had much less intellectual power, it seemed, than we have. So human society in those days would naturally be very low in organisation, and very poor in material resources. A long process of evolution was needed before the brain of the human race became larger.

Unfortunately, Huxley was entirely wrong. Instead of the Mousterians being in brain capacity nearer than we are to the man-like apes, they were, if other things had been equal, our superiors in mental power. They had an average brain capacity of 1600 cubic centimètres; and one skull has been found with the extraordinary capacity of 2,000 cubic centimètres. The brain of this man must have weighed more than that of Bismarck, who had a brain capacity of 1965 cubic centimètres. Of course, the size of the brain is not the only thing of importance in potential intellectual power. The ultimate structure of the grey matter, the degree of perfection in the adjustment of parts, and the nature of the blood-supply are probably factors of equally high value.

On the other hand, the size of the brain is a rough but safe measurement of potential mental power. The male gorilla, for instance, has a brain capacity of 600 cubic centimètres; the fossil ape-like man of Java has a brain measurement of about 850 cubic centimètres. The astonishing advance to 1600 cubic centimètres shown in the skulls of the Mousterians must have an intellectual significance. All modern anatomists are agreed upon this point, and they are now quarrelling with the geologists as to the date when modern man appeared in Europe. Dr. Arthur Keith is prepared to go as far back as three hundred thousand years; Professor Sollas, of Oxford, is inclined to think that one hundred thousand years is rather more than sufficient.

It is not for us to attempt to decide the point. We have a problem of our own to tackle in connection with the evolution of human society, which is now made very difficult. For the fact that Huxley was wrong goes to overturn many of the pretty theories of the origin of human society. For here we now find in Europe, say, one hundred thousand years ago, a highly intelligent race, who, in spite of their intelligence, scarcely made any progress towards civilisation. They lived in scattered families, in caves, knowing nothing of the arts of agriculture. They had not domesticated any animal, and in one of their dens something very like the remains of a cannibal feast has been discovered.

Indirect evidence of their intellectual power is obtained from the animal bones in their caves. The Mousterians feared nothing. They were very fond of the immense cave-bear, a beast more powerful than the Polar bear, and they killed it with ease. It was, in fact, their favourite food. They slew the hippopotamus and the rhinoceros, the bison and the mammoth. The Mousterians fought at close quarters with rude weapons of stone; and we may be sure that it was not with their flint axes that they fought so much as with their incomparably large brain. In them, the first Europeans of whose bodily remains we have any

considerable knowledge, the fiercest and strongest beast at last met his master.

The Mousterian is very useful to us. He shows that a race of Bismarcks, though practically lords of the earth, are no better than the ape-like men of Java if they have no social forces behind them making for civilisation. One of the favourite games of the student of human society is to imagine what would the best minds of the present age do if they were set to work out their lives without any help from society. Well, we know now from the Mousterians what would happen. A civilised man, with an unusually well-developed brain and splendid powers of body, would merely become a mighty and a cunning hunter of a deplorably savage type. Individual intellectual power, left to expand in a state of nature, and uninspired and undirected by the manifold social forces of our civilisation, could do little or nothing. The man might, with great trouble, invent a lance, as the Mousterians did, and arrive, like them, at some sort of religion, but when he was forced to trade almost entirely on his private stock of reasoning he could not do a really profitable business.

Was Man Originally a Social Animal or Did He Dwell Suspiciously Aloof?

As the science of man now stands, there can be no presumption that civilised society is simply the creation of a gradually developing mental power in the individual man. Society is born of the action and interaction of social forces. These social forces, on the other hand, came into existence through the play of mind on mind, character on character, will on will. To produce them it was necessary to get men to live and work together. Here we seem to detect the original social force from which the rest were developed—the force of gregariousness. If we can prove that the earliest types of man roamed the world in fairly large communities, we can clearly establish the primal starting-point in the evolution of human society.

Unfortunately, this is just what we cannot prove. There is no reason to suppose that, when man came down from the tree, he was a social creature. What little evidence we have bearing on the matter points, indeed, in an opposite direction. The earliest human group seems to have consisted of a strong adult male, with probably several females and a fairly large number of young offspring. Food was hard to get; and when the group found a source of food it fought off all intruders. When man became a hunter of small game his desire for loneliness was increased; he hunted for the family group, and he wanted no stranger to interfere with his females, or disturb the animals he was trying to catch.

Thus we see there were no forces from the outside tending to make him more social; the economic factor, indeed, served to keep him in lonely family groups like those of the man-like apes. But men had to come together before they could pool their energies and establish the rudiments of society; and we have therefore to discover the force which gradually compelled them to co-operate. This force must come out of the family group; and perhaps we shall not go wrong in assuming that it originated in a development of the parental instinct.

The Wonderful Socialising Power of Motherly Affection in Earliest Times

We have already given a sketch of the original family group as worked out by Messrs. Atkinson and Andrew Lang, but, in order to make clear our present point, we must again refer to the theory of the origin of primal law put forward by these ingenious authors. The primitive society was a polygamous family, consisting of a patriarch and his wives and children. As the young males became full grown, they were driven out of the community by the patriarch, who was jealous of all possible rivals. Some of the mothers of the young men, however, could not help being still attached to them by the kindly bond of maternal affection; and this bond became stronger as the powers of heart and mind developed in the human race. It is unreasonable to assume that a creature with much more brain-power than a gorilla would not grow responsive to natural feelings as its wonderful power of memory became larger and keener.

The Balance of Force that Arose Between a Mother's Love and a Father's Strength

So the young males at first formed semi-independent bands, hanging perhaps on the skirts of the family group from which they had been excluded. Now and then one of the strongest of them would attempt to master his jealous sire, and in the end the aged father would be conquered. Such is the system which the fierce sexual jealousy of man and his polygamous tendencies would produce in the absence of any modifying law or moral tradition. It is likely, however, that this system obtained in full force only in the pre-human stage of culture, and that when more human feelings were at work in the heart and mind of man the

COMMUNAL WAR ON THE MAMMOTH

One of the influences that brought men into closer social relations in the early days of the race was the need for combination to resist or overcome the huge animals of antiquity, as shown here.

young males were often allowed to remain in the family group.

But the idea of law had been born. For their strong and jealous sire naturally continued to forbid them from marrying within the group. When the young man wanted a wife, he had to win her in some way from a strange group. Thus the greatest idea in human society had been created—the idea of law. The love of a mother and the strength of a father had first conflicted, and then come to a kind of balance of force; and out of this balance of force a law had been created which made possible the extension of the small primal family group. In short, the family began to develop into the clan. But more important in some respects than the increase in the numbers of the group was the mental effect produced on the minds of the members by the new custom. It is an absolutely necessary condition in any kind of human organisation that the individual should control some of his impulses and acquire some degree of foresight. If this is not done we cannot get beyond the pre-human family group, in which there is no room for the play of any emotion except those of anger, desire, and fear, directed to some immediate end.

Mental Enrichment a Consequence of Self-Control and Social Convention

Man had to learn to tame himself, to practise self-control, before he was able to live at peace with some of his fellow-men. When the primal law was established, young men, who had only been restrained by fear, became humanised and gently disciplined by the force of a convention. On the one hand, their new powers of self-control gave them a richer self-consciousness, which made for individual mental progress; and, on the other hand, it led to an increase of strength in their social tendencies. They became more gregarious in nature, more sympathetic in feeling, and capable of being more strongly swayed by regard for the sentiments of their fellows. In this way there was also strengthened the influence of the public opinion of the group on each member of it.

What social force came into operation when the family grew into the clan, it is difficult to determine It may have been religion; it may have been war; it was probably both. At least, signs of both can be traced among the extant remains of the Mousterian race. There are the vestiges of a cannibal feast, which, it is only fair to add, may have been held by an earlier people with somewhat less brain capacity. The remains were found near the village of Krapina, on a tributary of the Danube, in Croatia; and the river has deepened eighty feet since the cave was used. The Krapina man had discovered the use of fire, but it looks, from the nature of his food, as if he were only a beast in human shape. Above the hearth that he used is piled twenty-four feet of earth and rubbish. There are nine distinct levels, each showing signs of human habitation. Let us hope that the Krapina men suffered the fate of the Kilkenny cats; they had brutish bodies, beetling brows, and massive jaws, and their teeth resembled those of some negroid races.

The Surprising Earliness of a Belief in Continued Existence After Death

No signs of cannibalism have been found among the Mousterians; and from the tremendous size and power of the animals they attacked, and attacked very successfully, it is clear that they must have gone on their big hunts in clan groups. Among them we find the first clear evidence of a belief in immortality. Three years ago, in a cave by a little stream flowing into the Dordogne, the grave of a Mousterian was discovered. The body had been placed in a shallow pit, and around it lay a great number of well-worked implements, fragments of ochre, and the remains of food. Undoubtedly it was a ceremonial burial, accompanied by offerings of meat and weapons for the use of the dead man in the spirit-world. The French discoverers received a shock of surprise on finding this well-known custom, and all that it implies, already in existence among the Mousterians.

The Enormous Formative Social Force of Man's Early Religious Ideas

The men of science who hold to the great antiquity of this race, which was swept southwards in one of the Great Ice Ages, have to believe that the religious beliefs and customs of the hunting races have scarcely changed for a quarter of a million years. But, as we have remarked, a hundred thousand years is, when the geological circumstances are fully considered, a more likely estimate.

But, however long the rudimentary ideas of religion have existed among men, it is fairly easy to calculate how large a social force these ideas must have been. We have seen that man is not naturally gregarious. Of course, he likes the company of his fellow-men when circumstances make him social. His mind is shaped for the pleasures and the profits of intercourse; he is marvellously responsive, not only to thoughts

IN LEAGUE AGAINST THE CAVE BEAR

That men must have united in groups to destroy the cave-bear is obvious from an examination of its bones, which show the creatures to have been far too formidable to be attacked single-handed.

and feelings, but to suggestions; and he is as imitative as a monkey. His nature feeds on social companionship, and the lonely savage is moved to ecstacy when he dances and sings and acts with a multitude of his fellows. All this is natural in a way; it is a sign of progress, a sign of enlarging sympathies and a growing mind. But we doubt if it is natural in the sense of being primitive. For primitive man, as we have seen, wanted to keep his sources of food to himself, and he would at first fight to the death to prevent another male from entering the family group. Harsh economic conditions and savage feelings of anger, jealousy, and selfishness prevented, for probably a long time, the development of human society.

Man's Early Attempts to Propitiate the Mysterious and Awful Powers He Felt Around Him

Religion, however, and magical rites and festivals did much to bring men together. We have clear evidence that the Mousterian of the Dordogne believed in a life beyond the grave; and it is a fair deduction from this that he held to most of the ideas which are still found among savages at a similar [illegible] is to say, that since he [illegible] were represented in the [illegible] flint-tools, and his meat by [illegible] must also have thought that [illegible] about him had a sort of spiritual essence. This being so, he must have tried—as all lower races still try—to mould the whole world to his desire by practising various magical rites. Savage religion consists of two parts—religion proper, in which feelings of fear and awe, and more rarely love, are expressed in connection with the strange, unknown, mysterious, and awful powers which the savage feels surround his life; and magic, by means of which he tries to do some of the things that modern science now enables us to perform.

The Magical Rites that Brought the Clans Ceremonially Together

All that the savage does not fear he attempts to master by a very primitive and ridiculous sort of science. If game is scarce, he thinks he can make game abundant; if there has been a long drought, and the deer have disappeared in search of fresher pasturage, he thinks he can make the rain fall and bring up the grass so that the deer will be tempted back, and wild fruit and wild vegetables grow in profusion. So strong is the idea of the savage that he is the lord of Nature that he often thinks the animals and plants on which he feeds would perish utterly off the face of the earth if he did not make provision for their continual existence.

One of the most curious relics of the Old Stone Age in Europe is a carving representing a number of men dressed up as animals and performing a magical dance. The carving is somewhat later in date than the age of the Mousterians, but there can be little doubt that, though the Mousterians were not such fine artists, they engaged in similar dances. They were like the cock in Rostand's play "Chantecler," who thought that the sun would not rise in the morning unless he aroused it by his song. Primitive man believed that nothing that he wanted to obtain could be made to flourish unless he performed various magical rites and dances and pantomimes at certain ceremonial gatherings of the clans.

How these gatherings originated, it is now impossible definitely to ascertain. Either of two theories will account for them. It may be that the family clan began to practise magic in a small, exclusive way; and then, as the clans expanded in numbers, the rites were further developed and maintained as a socialising and binding force between the related but far-scattered communities.

The Persistence of Old Observances Into Days Within Range of History

On the other hand, common needs may have brought a number of stricken communities together; there may have been a failure of the game or other means of food; or some vast cataclysm may have occurred when the Great Ice Fields were creeping down from the North Pole, and driving all the races of men from their accustomed haunts. The natural growth of magical rites strikes us as the better of these two theories.

So we shall conceive some of the earliest races of men being brought together at stated seasons of the year, for the practice of rites which were partly religious, it may be, but mainly magical. At the present day, reunions of this sort form the main social force among the blackfellows of Australia, and other savages of a very low type. Moreover, similar religious customs and feasts can be traced among the Greeks and the Romans. As Fustel de Coulanges says: "In times of peace, and in times of war, religion intervened in all the acts of the pagans of Greece and Rome. It was present everywhere, and the individual was enveloped by it. The soul and the body, private life and public life, banquets and feasts, and assemblies and tribunals of law were all under the empire of religion. It regulated all the actions of a man, disposed

of all the moments of his life, and fixed all his habits. With so absolute an authority did it govern the human being that outside of it nothing remained of him. It was a loose collection of little beliefs, of little practices, and of little rites."

In short, it was a tribal religion. Built up first in the festivals of the hunting age, where magical dances and pantomimes were used to subjugate the spirits of animals and make an easy prey of them, this religion gradually extended its power over the whole of human life.

The Rise of the Aged as the Repositories of Experience and Wisdom

So far as we are able to judge by what takes place among existing savages, the older men of the clan began by meeting together and holding a council. They were the only receptacles of the traditions of the clan, and with each development of these traditions their spiritual authority became greater. They won their position naturally by reason of their longer experience and their longer memories; and they made the occasion of initiating young men into the customs of the clan a ceremony of very great importance.

Sometimes we find at the present day that one of these old men has become in an especial way the master and medium and practitioner of the chief rites and superstitions. This is the first step to kingship, and we can still trace the steps by which the witch-doctor becomes a great chief. This process has been very thoroughly examined by Professor J. G. Frazer, who clearly shows that the strange mixture of policy and superstition of which the witch-doctor became the director was one of the most powerful of social forces in these primitive times.

The Strange Way in which Some Goodness is Distilled from Evil Customs

Even when the idea of an All-Father had faded from the minds of men, leaving their creed nothing but a wretched amalgam of witchcraft and magical ritual, the rites and the customs and beliefs were still potent to keep scattered clans united in tribes, and to give tribes some glimmering idea of nationality. In the absence of literature and science, a communion of superstitious beliefs and practices kept a race together as no other social cement could have done.

There is a soul of goodness in things evil, says Shakespeare, if men observingly distil it. In one way nothing has done so much to retard the progress of mankind as the extraordinary amount of superstitions and superstitious rites which men have accumulated. In many cases these superstitions made man more cruel and savage than he was naturally. Cannibalism, for instance, is often a superstitious custom; it is connected with human sacrifice, which in turn seems to have developed out of animal sacrifice. Yet superstition and magic may, in the beginning, have been but a misdirected but well-intentioned attempt to create a body of useful beliefs and rites, which brought men together and helped to socialise and unite and organise them.

Moreover, we find in the grave of the Mousterian of the Dordogne evidence of that regard for an ancestor which, even at the remote age in question, may have been transformed into the elements of ancestor-worship. Beginning with the superstitious fear that the spirit of some great dead man would haunt the camp—where no doubt he was often seen in dreams after his death—this dread of ghosts developed into one of the finest and most magnificent of social forces.

Love, Casting Out Fear, Led the Simple Early Man Towards Ancestor-Worship

Fear, indeed, was at last cast out by love; and the feeling that the fathers of the race still exercised a spiritual direction over the fortunes of their descendants gave an extraordinarily binding and consolidating power to the rites that kept the memory of common ancestors alive in the clans.

Only a few years ago the modern Japanese, after emerging victorious from the most eventful war since the battle of Marathon, astonished the world by publicly attributing all their victories to the spirits of their ancestors. The fact is, there is a sound core of scientific truth and social strength in ancestor-worship. Our individual triumphs and our national progress are largely due to the struggles, the self-sacrifices, and the honest lives of our forefathers. The work which they did, and the traditions which they established, are the strong foundations upon which we are able to build. By honouring them and keeping their memories alive, a people ensures that continuity of national life which is the grand factor in civilisation. Nowadays literature and the fine arts keep fresh and clear in the mind of a nation many of the great achievements of the leaders of the races. In primitive, savage, and barbaric ages the rites of ancestor-worship served a similar purpose, while at the same time exercising a peculiarly socialising influence on all the scattered communities which retained the tradition of a common descent.

We have now reviewed two of the great social forces the operation of which we can dimly discern among the most primitive races of men. We have found that, when the idea of primal law arose, the family was able to grow into a clan, and that, when the idea of a spirit-world was dimly grasped, rites and festivals were instituted which brought men together, in a state of intense emotion, and filled them with a quick and pregnant sense of fellowship. In many parts of the world ancestor-worship arose and further consolidated the wandering clans of hunters, and became probably in the pastoral age a social force of very great value. All this evolution of the mental fabric of society was accompanied by certain economic factors of a socialising kind.

The development of the arts of hunting, for instance, taught man the value of co-operation. While he was content with small game, he preferred to act by himself, and resented any intrusion upon his hunting field. When, however, his powers of mind and his strength of character increased, and he went forth boldly on man's high task of subduing all the life of the earth, he found that mutual aid was necessary, and discipline and skilful combination. And when at last, by fighting daringly and cunningly in bands, men conquered the cave-bear and rhinoceros and bison, they achieved something more important than victory over the wild beast. They achieved a victory over their individual selves, and from this victory the spirit of human society was born. Men had learnt to work together for the common necessities of life, and they had arrived at a position where they only wanted a knowledge of farming to attach them to the soil and inspire them with the ideal of a settled civilisation.

A MOUSTERIAN CHOPPING TOOL

This flint implement, found in the cavern called Le Moustier, has a curved cutting edge, a part being left unchipped to enable it to be held with a firmer grip.

For good or for evil, however, they had first to pass through a long period of warfare before they arrived, in the New Stone Age, at a settled way of life. Undoubtedly war has often been a social force of high importance. When, in any region, social organisation advanced to the point at which the mortal combat of individuals was replaced by the mortal combat of clans or tribes, a terrible process of moral selection was begun. No doubt the vigour and ferocity of individual warriors made for the survival and increase of the clan, but the individual factor was not the main one. The issue chiefly depended on the capacity of the clansmen for united action, upon their good comradeship, upon personal trustworthiness, and upon the ability of individuals to master their impulsive tendencies and their selfish promptings, and subordinate themselves to the larger interests of the group, and to the commands of the accepted leader. Thus wherever wars between clans and tribes went on for many generations, the continual struggle must have developed in the surviving groups the social and moral qualities which are essential in all effective co-operations and in all the higher forms of social organisation. The more the pugnacious instinct impelled primitive societies to warfare, the more rapidly and effectively must the fundamental attributes of men have been developed in the societies which survived the ordeal.

Dr. William McDougall gives an instance of the moral and social effect of continual warfare among the tribes of Borneo, among whom he has lately been staying. Travelling up each of the large rivers he met with tribes that are successively more warlike. In the coast regions are peaceful communities which never fight, save in self-defence, and then with but poor success; while in the central regions, where the rivers take their rise, are a number of extremely warlike tribes, whose raids have been a constant source of terror to the communities settled in the lower reaches of the rivers.

It might be supposed that the peaceful, coastwise people would be found to be superior in moral qualities to their warlike neighbours, but the contrary is the case. In almost all respects the advantage lies with the warlike tribes. Their houses are better built, larger and cleaner; their domestic morality is superior; they are physically stronger; they are braver, and physically and mentally more active, and in general are more trustworthy. But, above all, their social organisation is firmer and more efficient, because their respect for and obedience to their chiefs, and their

loyalty to their community, are much greater. Each man identifies himself with the whole community, and accepts and loyally performs the social duties laid upon him.

By the dreadful engine of war clans have been forged into tribes, tribes welded into nations, and nations riveted into empires. It was the Roman sword that made peace in the ancient world, and the English musket that transformed India into so quiet and safe a continent of peoples that the population is now developing to that extreme point at which it outgrows the natural supply of food. Thousands of times, no doubt, have fierce, ambitious men misused the engine of war; and it is probable that we have now reached a state of civilisation and a state of conscience at which instruments of consolidation of a pacific kind have become more generally effective than the red hand of the warrior. But though we may have sound reasons for at last throwing aside the weapons of battle, we must not sentimentally blind ourselves to the fact that war has sometimes been a social force that made for progress.

The Terrible Weapon that has Sometimes Set Right the Oppression of Law

War was the only social force of ancient times which was capable of overcoming the excesses of tribal law and tribal conventions. Law, as we have seen, is the first necessity of society. In primitive communities it always has a religious and overwhelming importance; and, if unchecked, it tends so to restrict individual freedom and initiative that a race becomes, as it were, fossilised by its conventions. The brain capacity of some of the very lowest of existing savage people is not inferior to that of hundreds of thousands of members of the most progressive nations in the world.

But in the savage all faculty of invention is stifled by religious taboos, and customs and superstitions. So we get races like the Tasmanians, who made no advance for three hundred thousand years or more. The Tasmanians are now extinct in Tasmania, but they live on in Australia, where they have been raised to a somewhat higher level of culture by a race of invaders, who fought their way into various parts of the country, and intermarried and introduced a system of new ideas and new customs. A similar thing happened more recently in Mexico, and along the coasts of South America, where a population that still has a great deal of Red Indian blood in its veins has been lifted up to a high state of civilisation by a series of cruel and apparently tyrannical conquests by two conquering nations of Southern Europe.

In the conflict of modern civilisations and national varieties of civilisations there must needs be some instrument of decision. Competition of some sort is necessary to decide what living ideals shall prevail, and mould the lives of future generations of men.

How the English People Spread Their Free Institutions by Fighting for Them

The ordeal of battle is a very rough and a very dreadful way of selecting these ideals, but in the past it was not ineffectual. Would our system of representative government, and our system of trial by jury, have been universally copied if our forefathers had not proved on the battlefield how strong free institutions made a people? It was not until we were practically the masters of India and North America that the nations of the Continent began to take an intelligent interest in our social and political civilisation. And perhaps it is because the Anglo-Saxon races are still strong in arms as well as in industrial power that they, like their forefathers, are recognised throughout the world as the champions of personal and political freedom.

"Might must reign," says Joubert, "until right is ready." Happily, the civilised world seems now to have developed a fund of culture—religious, political, social, scientific, and artistic—sufficient at last to serve as the greatest of social forces. At the present moment we are witnessing in China the effect of the living ideals of the Anglo-Saxon race on a highly intelligent people, whose national genius has been cramped by outworn customs and conventions. No terrible and devastating conquest was necessary here; neither was it necessary in Japan.

The Coming of the Age of Peace, and the Increasing Power of Moral Qualities

Conflict and competition there needs must ever be, so long as progress depends on the selection and development of the existing best, and on the sifting out of the second best and the bad. But, fortunately for mankind, we seem now to be entering on the peaceful conflict and competition between ideas and inventions and moral qualities. Race suicide takes the place of war in a nation that is growing weak through selfishness. It may be a slower and more pleasant process of extinction, but it is more deadly. While human societies exist, some selective force, plain or subtle, will be in operation, but war is ceasing to be a creative social force.

AN EDUCATION SYSTEM GONE ASTRAY

THE WRONG WAY OF DEVELOPING A CHILD'S BRAIN—DISCIPLINED WORK IN A CLASSROOM

THE RIGHT WAY OF DEVELOPING A CHILD'S BRAIN—UNFETTERED PLAY IN SUNLIGHT AND FRESH AIR

FROM CRADLE TO SCHOOL

The Years when the Brain is Growing, the Frame Forming, the Bones Hardening

GIVE THE HOME-CHILD A CHANCE

THERE is a notable contrast between the course of legislation and the course of logic. In recent years the problems of nurture have received, or are receiving, legislative attention at the extremes of life, beginning at the end with Old Age Pensions, and now turning to the beginning with "Maternity Benefits." But our business here is to deal with the problem of Nurtural Eugenics in the order of time and of causation.

We necessarily began, therefore, with the beginning of the new individual, which involves us in the study of expectant motherhood and ante-natal nurture. There followed the second stage of nurture, which we may call infancy, and which is distinguished by its only normal nutriment, the mother's milk. This period ends with weaning, which repeats, on a very much diminished scale, the change of diet and nurture that occurred when the child was born. Hereafter the diet of the new individual must be chosen for or by himself, and will always offer problems which did not exist in the periods of gestation and lactation. The child, an infant no longer, begins to talk and to walk, and becomes a personality, with will and choice and desire and idiosyncrasy. In the course of a few years it will be expected to go to school, and will then become a member of the most important and definite constituent of the nation, that is its school-children.

From the point of view of national history and national practice, it must be remembered that the nation discovered the next generation under the guise of the school-child, and that even to-day it is only the school-child that is, so to say, publicly recognised. But the school-child was a child before it went to school, and an infant earlier still, and the school age is too late for its discovery. Besides, there is the question when schooling should begin, and we cannot very well decide when to make the child into a school-child without noticing that it is a child already. Public and political opinion have undoubtedly discovered the infant within the last few years, and there are signs that we shall soon discover adolescence. The school-child having been noticed for a generation and more, there being no doubt about the adult nor the old age pensioner, and expectant motherhood having now come under the eye of the law, there remains only the period of life between infancy and the school age, and that is the period which falls to be considered here.

It is perhaps permissible to suggest that what the public wants is a name to focus its attention. The infant, the school-child, the adolescent—all have definite names, and call up a definite picture. Failing a better, we shall here speak of the child, as we find it when it is no longer an infant and not yet a school-child, as a home-child. Not having been employed before, the term appears uncouth, but it may sound just as natural as school-child before we have finished with it; and we may be able to show that it is not only a name, but also a definition, an indication, and an ideal.

The students of development give us a definite reason why the period of life between weaning and about seven years of age should be identified and considered apart; and it is on this ground, rather than the law regarding the school age, that we here identify the home-child. The brain undergoes rapid development, well in advance of the body—which depends upon the brain for its development—during the first septennium of life. At about the end of this period all the elements and constituents of the adult brain can be identified; and its subsequent increase even in weight

alone is very small. It has lately been shown, by Sir James Crichton-Browne, that the facts have been slightly overstated. There *is* some development of the structure, as also of the size, of the brain after the seventh year, and there is even evidence that some development of the brain is possible far on into maturity, but this new evidence only brings out more clearly the remarkable fact that the first septennium substantially embraces the development and construction of the brain, once and for all.

The Need for Nurture Rather Than Schooling in the Time of Brain-Building

It is the period during which this machine is being constructed, and the facts most forcibly suggest that it is therefore not the period during which the machine should be more than spontaneously and easily used. The process of instruction, commonly called education, should evidently be deferred until the machine is made, but the process of true education or nurture, during that period of construction, which can never be recalled, should be as perfect as possible.

In other words, what we here call the home-child is a child whose brain is being constructed, once and for all, and its construction is the supreme concern of all wise nurture during this period. We may suppose, if we like, that education, so-called, constructs the brain, and therefore that we must ply the child with letters and figures and facts. That, however, is not construction, but instruction combined with destruction. For the moment we must think of the brain as if it were any other organ, a muscle or a bone. The material substance of the brain has to be provided in the diet, then digested, absorbed, and built up into the predestined structure. Our business is not to instruct, but to permit construction.

Seven Years of Age the Right Time for the Beginning of Schooling

The child must have the right food, air, light, sleep, clothing, exercise; the right psychical influences of love and peace and safety no less; and then this all-important period of brain-construction will be successful. If the child's hereditary composition or nature be sound, if its first two stages of nurture were adequate, and if this third stage be so also—thereafter its brain will learn with ease and pleasure, and none can say how far it may not go.

We do not here assert that every child's brain development proceeds at the same rate. That would be folly, and least of all excusable in the Eugenist, who asserts human difference. The inequality of rate complicates the national problem of the school age, but that problem must be faced. We here lay it down, then, that the approximate age, the only one that can be named if we are to have a definite age at all for the beginning of schooling, is seven years.

If any suppose that the beginning of schooling and the beginning of education are the same thing, there is no more to be said to them. Here we speak of schooling. We lay it down that real schooling, with all that it necessarily and rightly involves of enforced attention, which is mental discipline, of enforced confinement, which is bodily discipline, and of reading, which is severe ocular discipline (all young children being normally long-sighted), is an improper process to which to submit the child before it has reached, let us say, the age of seven.

The Late Start that Gives Children the Best Chance of Winning the Race

This is not to say that any schooling may not be better than some homes. It is not to say that schooling is incapable of such modification, as in the "kindergarten," or "child's garden," that it becomes something else in all essentials. But it is most definitely to assert that the modern study of development condemns the practice of ordinary schooling, or any modification of it that preserves its identity at all, during the first septennium of life.

The child during this period should be the home-child, not the school-child. Fond parents may seek to anticipate schooling, especially if the child shows signs of precocity. No wise student of human nurture is overpleased with precocity; no real observer, wise or unwise, can suppose that precocity is to be encouraged. The reformer has to preach, in season and out of season, that on no account must we prejudice brain-construction. We may start using the machine, putting material into the mill, when it is only half made, and may even get results, but we are liable also to get the further result that the machine will never be wholly made, or that, even if it be so, it will soon wear out.

Those who fear that their children will become backward, and lose in the race for life, require to be met with the definite evidence, abundant and detailed, from all parts of the world, which shows that children whose period of brain-construction has been understood and duly circumstanced

walk into school at the end of it and in a few months far outstrip their neighbours who may have already been grinding away for years—with mills only half made.

The Eugenist, therefore, while making many demands on the legislature and public opinion, including a demand for the great extension forwards of the school age, as we shall see, begins by asserting that the great majority of the nation's children go to school too soon, and that we should get incalculably better results from the school-child and the adult if we would only begin by recognising and trying to understand the home-child.

The Danger of Infectious Diseases that Surrounds the Young School-Child

The recent study, by "Medical Inspection," of the health and disease of school-children adds much force to a most important argument on which the writer has been insisting for years. It has shown how grave are the sequels, to which only death writes "Finis," of those infectious diseases that flourish in the school. To send a child to school is to expose it to infection, on the generous principle that what one has all should have. The recognised maladies of childhood, far too lightly looked upon by the public, are mainly caught and spread at school. If they were all inevitable, if they left no permanent results, and if the sooner they were caught and done with the better, our system would be sound.

None of these propositions is true. Childhood is the period of greater susceptibility to most, though not to all, diseases. Who that knows anything of life at all would expect the case to be otherwise than that the immature organism should have less power of defence against deleterious agencies of any kind—microbes, burns, cold, hunger, or what you will? Hence, in many cases, if the infection can be avoided for some years, the child may by then have outgrown its susceptibility, and may thereafter be exposed with a fair chance of escaping.

The Serious After-Effects of the Ailments of the School-Child

Many well-cared-for children thus escape such a disease as, say, scarlet fever; and in later years such children, as medical students, doctors, or nurses, may be closely exposed to the disease without catching it. Now that we are beginning to learn, on an appallingly large scale, what are possibly the local consequences of such diseases as this, even when recovered from, which is by no means always the case, we should surely see that it is worth while to avoid them altogether if possible, and that may largely be done by protecting children during the most susceptible ages.

For the diseases of childhood, thus spread by the school, leave local consequences of the most serious character. Our land is full of children who have defects of nose and teeth, and glands, and ears, and throats, and eyes, and hearts, and kidneys which are the results of these infections, and for most of them only very partial cure is at all possible, even if the national machinery for cure existed and were applied.

Not only present and future readers, but the nation at large, will realise, within the next five years at the very most, that the state of the nation's school-children is a pressing and imperative problem, with proportions and consequences hitherto unrealised. We shall then begin to ask ourselves, as the hopelessness of the problem of "cure" and "treatment" becomes apparent, whether this state of things cannot be largely prevented, not least, perhaps, with reference to the cost of National Insurance during adult life; and it is just then that the nation at large will discover what we now call the home-child, and will come to see what is essential for the control of these lamentable infections and their permanently crippling consequences, alike to the individual health and to the national exchequer.

The General Superstition that Children's Diseases Must Come and had Better Come Soon

In the intervening period the public will require to be disabused of a very general superstition which is here exposed—that, these infections being inevitable, the sooner they are caught and done with the better. The facts are that this "getting them over" is largely a myth, for it is much less the previous attack than the advance in age that protects the adult; and the serious cases in adult life, the number of which is greatly exaggerated, are probably just as likely to occur in people who have had an attack in childhood as in others. The public should learn the real facts about these epidemics of childhood, should take them far more seriously than hitherto, and should seek to diminish their intensity and consequences by far more complete protection of children at the most susceptible ages. This is one of the most important and practical of all arguments for the recognition of the home-child, and for the postponement to a later than the present age of that close

herding of young children in confined spaces which we call national education.

It may justly be replied that, only too often, the schools are far superior, as homes, to what should be the children's homes. Slums and married women's labour do not exactly conduce to the right "provision of an environment" for the home-child, but if we believe, with King George and every wise person that ever existed, that "the foundations of national glory are set in the homes of the people," we must plainly not content ourselves with trying to improve the conditions of schooling at ages when schooling is premature, and therefore improper. Those who, for one reason or another, are the professed or covert enemies of the family and the home naturally prefer to encourage expenditure and effort for the provision of schools of all kinds; but if the dictates of physiology and of psychology agree with the teaching of history, that, for the first septennium of life, "there's no place like home," then we must reconstruct our policy and purpose towards the restoration of the home rather than its replacement.

The Eugenist's Duty—To Point Out what is Scientifically the Best

As things are, the Eugenist welcomes the schoolroom, the "vacation school," the "open-air school," the "nursery school," and so forth, as we welcome the infant milk-dépôt and the crèche, in default of better things; but it is precisely the business of the Eugenist, who builds his case on science, and cares nought for class or party or any political creed, to say that there is no ultimate substitute for the mother's breast in infancy, nor for the mother's home in the years that follow. The time may not have come to act upon the knowledge which declares that a compulsory school-age of five, and an optional school-age of three, are outrages upon the laws of nurture, but the knowledge remains, and we must act upon it as soon as possible.

It goes without saying that the right nurture for the home-child is the right kind of home, which depends upon the mother, who is the chief home-maker, and upon the father. No physiological or medical advice can equal or replace these primary necessities.

The period we are now discussing begins when the child is weaned. We have already shown how the observed facts of mankind suggest that that process is rather to be delayed than hastened. When it is made we have to face the primary fact that the child is now to be so fed as to avoid the attacks of dangerous microbes. Before its birth the child's diet was perfectly and exquisitely filtered of microbes by means of the maternal portion of the organ called the placenta, or "after-birth." When the child was a suckling its actual diet was no less perfectly protected from infection by means of the cells that compose the mammary glands, and its diet was microbe-free, though infection by dirty receptacles, if the child be not breast-fed, is unfortunately a matter of everyday occurrence at this period.

Deficiencies and Dangers in the Diet of the Home-Child

But, after weaning, the child's actual diet is open to danger, and our first duty is to guard it in these respects. Food and food-utensils of all kinds must be kept clean. Cooking is invaluable in many cases because it kills microbes, and cooked food is therefore usually sterilised food. But the most important aspect of the nurtural eugenics of the home-child, especially in its second year, has yet to be stated. We have been duly prepared for it by our observation as to the customary length of lactation among savage mothers.

It is that the diet of children in their second year, taking the nation as a whole, is far too deficient in milk. The comparative study of man has shown us that the child might very well be taking its mother's milk, as the whole or greater part of its diet, throughout its second year. If we have weaned it, let us at least remember that milk, in one form or another, is still the best diet for it. As we have seen, the child's stomach now acquires the power to digest starch. Foods containing starch, including such staples of diet as bread and potatoes, now become possible in some degree, as they were not in the first year of life, but milk (which contains no starch) remains the best and most essential part of the diet.

The Great National Question of an Adequate Supply of Pure Milk

In the United States of America the risks run by children in their second year, in consequence of parental ignorance and carelessness as regards diet, are well known to those whom the knowledge pays; and advertisers prescribe, often not unwisely, their special wares for "Baby's Second Summer." Many of the advertised foods might be commended in this connection, especially those which are more or less partly cooked and digested, and those which are directly derived from wheat, oats, or milk.

But fresh milk retains its premier place, and does so notwithstanding two great difficulties which must certainly be dealt

with somehow, if our national life is to grow in any degree adequate to our Imperial necessities. These are the quality and the quantity of the national milk supply. The quality, compatible with safety, can only be obtained at a very serious increase of the present expense. At present not only is good milk a vital necessity of nurtural eugenics, but infected milk is a source of grave and continuing national ill-health and inefficiency. But the question of quantity is scarcely less important. Milk for the children of country folk is almost unobtainable, and there is a constantly increasing and inevitable tendency towards a shortage in the towns.

The Elementary Rights of Infants, Invalids, and Mothers to a Supply of Fresh Milk

This is not an accidental or economic question merely; it depends upon the eminently simple fact that the number of persons, or, more narrowly, the number of children, in these islands increases every year, while our herds do not, and the import of milk is negligible. The use of powdered milk cannot do very much to meet the difficulty; and it is quite clear to the student of population that only two effective courses will be open in the future. The first is to increase the milk-supply of the country, at whatever cost in the way of employing land now unemployed. The second is to look upon the available supply of *fresh* milk—as distinguished from all forms of preserved milk, liquid or dried, and other dairy products—as being primarily the right of the infants and invalids, and expectant and nursing mothers of the community.

It may be remembered that milk, excellent though it be as part of the diet of the adult, is not a natural part of adult diet; and, further, that the infant and the home-child depend upon the freshness and the completeness of milk as others cannot depend whose diet includes other constituents capable of being made to compensate for any defects in preserved milk and its products.

A Disease of Infancy that is a Reproach to the Name of England

All this question is involved in the study, from the national and eugenic point of view, of our great national disease—rickets—which, outside these islands, is often known as the "English disease." The national importance of rickets is enormous, for it not merely leads to ill-health and inefficiency on its own account, but is the most effective of introductions for the tubercle bacillus, and such other enemies of adult life. Rickets is not a disease due to a microbe. It is not at all a question of the fight between one form of life, say man, and another, say a microbe. Those fights are really part of the struggle for life, and should be looked at from the biological point of view primarily. They therefore do not essentially concern us in this section, but rickets does, most intimately, for it is the great disease of malnutrition; and any eugenics at all, especially nurtural eugenics, which ignores rickets, its causation and consequences, merely plays with grave questions.

As in many other cases, the bad nurture which produces rickets is partly a matter of defect and partly a matter of poisoning—it depends both upon defective and upon improper feeding. Needless to say, a diet may be abundant, or superabundant, in bulk, but nevertheless defective in one or more ingredients—which may be vital. No child is born rickety. There are, of course, diseases of ante-natal nurture, but rickets is not one of them. The term "congenital rickets," still frequently seen, is a misnomer, for there is no such thing. All rickets depends upon malnutrition after birth.

How Mistaken Ideas as to the Cause of Rickets Lead Us from the Truth

It has here been assumed that during the greater part, at any rate, of the first year of life the infant is a nursling. Nurslings do not suffer from rickets, assuming that they have been breast-fed. Rickets is thus the characteristic disease of that period which we cover when we speak of the home-child.

The disease is so common and important, and its grosser symptoms are so familiar, that the public is well aware of its existence, and generally credits the long-disproved medical theory of its causation which ascribed it to defect of lime in the child's diet. The softness of Glasgow water has thus been held accountable for the abundant rickets of Glasgow children. Following this view, mothers and doctors have often prescribed lime-water for children, to be added to the milk—unaware that milk itself contains much more lime than lime-water, and that to add lime-water to milk in order to add lime is really to subtract lime from the child's diet, and to substitute water for a portion of its food. (It is not here asserted that lime-water has no use in making milk digestible in certain cases.) In point of fact, the proportion of lime in a child's diet has nothing whatever to do with rickets or its causation, and the theory dates

from the period of medical ignorance which was naïvely content to argue from the softness of rickety bones that lime was lacking in the diet of the rickety child.

It now seems clear that rickets is due to the defect of certain obscure but potent compounds in the child's diet—a defect from which whole fresh milk and properly made flour are free. The child fed on good milk and cream and upon "standard bread" is not a rickety child. Further, the knock-knees, bow-legs, and other bony deformities produced by rickets are the least important and least frequent part of the disease. It is a disease due to malnutrition; and its consequences are found not only in the bones of the skull, but in the brain underneath. The case of rickets that has affected the bones has already gone far too far.

Bad Feeding the Chief Cause of the Deplorable State of the Nation's Children

The most recent inquiry into the condition of our children at the school age makes it clear, on a scale which we shall realise when we come to study the problem, that malnutrition during the first septennium, showing itself above all in rickets and its allies, is *the dominant cause* of the existing state of the nation's school-children.

Expectant motherhood, infancy, the home-child, the school-child, the adolescent—all these terms express links in a living chain, at the end of which, and only through which, do we come to the adult. The strength of a chain is the strength of its weakest link, and we are gradually learning what links are weak and why. Under our system of national education, as revised during the last decade, we are learning about the link therein concerned. Under the Notification of Births Act, and the provision of maternity benefits, we are learning—and with the aid of a great national organisation, about to be formed, will still more learn—that we must attend to the link called the infant.

The Blind Spot in English Vision—Neglect of the Nurture of the Home-Child

These legislative improvements, and the systematic work associated with them, all ignore, be it observed, the period between infancy and schooling. That period is necessarily as essential as any other for the making of citizens. There is here a most serious blind spot in our national vision, and the present chapter seeks, if possible, to remedy it. "An Englishman's home is his castle," we say; and we believe in liberty. But there must be liberty for the nation's children to receive proper care and nurture; and if we are going to regard infancy and the school age, it is nothing but a national imbecility to ignore the period of what should be about six years in between them.

Exactly such assertions as the Eugenist makes when studying expectant motherhood and infancy he must make again in this relation. The chief reason, hitherto unperceived, why prevention is better than cure is the everlastingly final one that prevention is mostly possible and cure is not. In due course, then, we pass on to the study of national education, under the new and hopeful guise which it has assumed in the last six or seven years; but we here note that unless and until the nation recognises the home-child, the problems of the school-child will never be solved, nor yet any of the problems which occur at all subsequent ages, because the needs of brain-construction have been met with poison instead of food.

The prospect is not hopeless; far from it. No more is needed than to state the facts, and let them speak for themselves. The sentiment, the sense, the energy required for dealing with them already exist. Of this the proof is to be found in the one notable piece of legislation that for many a long year has been directed towards the needs of this period of nurture.

The Good Work of the Children Act, and the Harm It Does Not Touch

We refer, of course, to the Children Act, which came into force in 1908. Some there were who regarded it as the consummation and realisation of all that we can ask for childhood, but reformers would do well to be satisfied only when life itself ceases to ask for more. The Act conveniently codified much pre-existing law, and it made some useful additions thereto. It involves better protection for certain infants, and they and the school-child are further recognised to be less likely to thrive under the form of the public-house child, and are accordingly excluded from such places, with results which have won the hearty gratitude of official and unofficial inquirers everywhere.

While the Eugenist is necessarily thankful for these and similar benefits, he is compelled by the facts to point out that they merely deal with the fringe of the question. They attack certain obvious evils, and prevent some harm. But the conception of the Act is nowhere constructive, and the vast problem which really awaits solution is wholly ignored by it. That problem, in its most essential and urgent aspect, is the provision of right instead of wrong food for the nation's home-children.

BIRTH OF THE SOLAR SYSTEM

The Unsolved Mystery of World Formation from a Chaotic Whirlpool in the Spiral Form Unaffected by Outside Forces

WHERE THE NEBULAR THEORY FAILS

WE look at the solar system as a whole, we realise that it *is* a whole, and we are bound to ask its origin and the manner of its development, as we ask the origin and development of an oak or a cathedral. The overwhelming majority of mankind, in all preceding ages, as also now, would reply that the solar system, which we see to be a balanced and apparently changeless and stable thing to-day, was created by the Divine *fiat*, that the planets were made out of nothing, and launched on their course from the Divine hand. But science gives us deeper notions of Deity, and impels us to search for an explanation of the origin of the solar system which shall be natural and evolutionary, but not less ultimately Divine.

Just as in the case of the cathedral or bridge or oak, we must make certain assumptions for the present. We must be allowed to assume the existence of a certain quantity of matter. Whence that matter came, and where it had formerly been, are further questions still, needing further answer. Meanwhile, we are, so to say, given matter in some condition or other, and the problem is to make a solar system out of it.

Or, rather, the first problem is to decide what condition the matter was in when the solar system began to form. Here is a central sun with all these bodies that we have enumerated around it. The evidence is overwhelming that they were not always as they are, and that they have a common origin. What was the condition of the material from which they were made, in which they were crystallised, from the twirling edge of which they were thrown, or out of which they were carved? Evidently there is here a distinct and exceedingly difficult question, which requires separate consideration before we ask where at all this material came from.

What we may now call the classical answer to these questions is embodied in the famous nebular theory, or hypothesis, which gained general acceptance of astronomers for more than half a century, and is now, among thoughtful people, the generally entertained idea of the origin of the solar system. Though we shall be compelled to reject this theory in its original form, yet it remains one of the greatest and most fruitful conceptions of the human mind, and only through it and by its aid shall we ever be able to construct the completely true theory of the origin of our system. Let it be most clearly understood, in advance, that the rejection of the classical form of this theory is not a triumph for the enemies of science and the champions of "creationism," but is a stage further towards the precise understanding of the factors that have wrought this lesser cosmos of ours, the solar system, out of seeming chaos.

In his immortal poem on the "Nature of Things," Lucretius, the Roman follower of Democritus, the Greek philosopher of the atom, has a phrase about "falling atoms" and the making of worlds, which suggested to Kant, long ages afterwards, the nebular theory of the origin of the solar system, which was later given mathematical form by Laplace. Lord Rosse's great telescope demonstrated that many supposed nebulæ were only star-clusters, and thus seemed to deal a mortal blow at the nebular theory. Sir William Huggins proved that nebulæ do exist, and the nebular theory was reinstated, and enjoyed many years of little challenged success, until mathematical considerations, of a highly abstruse character, began to emerge, which showed that the theory, in its accepted form, could not stand. Such, in a word, is its history, and now for its nature.

The theory demands, in the first place, the existence of a nebula—which is essentially an aggregation of gas. When we study the nebulæ, we must ask all the questions which their existence suggests. Meanwhile, we accept the existence of a nebula from somewhere, made somehow, and probably very cold. This nebula, we suppose, would extend to limits which are more or less indicated by the present orbit of Neptune, and which must, indeed, have been considerably larger, but certainly not less large.

The Theory of a Gaseous Nebula Filling the Space Between Neptune's Orbit and the Sun

The nebula would not, at the time we are speaking of, be where the solar system is *now*, for we know that the entire solar system is in motion—from somewhere to somewhere—but we speak of the nebula whence the solar system began to be formed, wherever the nebula then was.

The theory asserts, then, that by the working of the forces inherent in this nebula, forces which we believe to have been in action ages ago according to the laws which we observe to-day, it has been resolved by a process of contraction into a central or parent mass which we call the sun, and into a number of subordinate bodies which we call the planets. The satellites of the planets are to be included also, though we may not be sure whether they were formed from the nebula as the planets were, or were formed by breaking off from their planets, much as, according to the theory, the planets broke off from the primitive sun. The origin of the comets, the asteroids, or minor planets, and the meteorites, assuming them all to be natives of the solar system, must somehow be accounted for in a similar way.

If there were such a Nebula it must be Spiral in Shape—and Nebulæ are Spiral

Now, certain facts appear to be clear. Given a nebula, or gaseous cloud, of any shape whatever, given even that its particles are moving to and fro in a condition of absolute chaos, around no centre, obviously without "order," and apparently without law; given, indeed, what is probably the initial state of all nebulæ—at their birth, which is "another story"—mathematics can clearly demonstrate, assuming the law of gravitation, that such a nebula *must assume a spiral form*. The chaotic nebula, left to itself, must become spiral. This fact stands, and is among the biggest in astronomy, explaining the extraordinary proportion of spiral nebulæ in the heavens, and carrying us a long way from the memorable occasion when Lord Rosse discovered the first spiral—or, as he called it, "whirlpool"—nebula, and the French critic said it was only a scratch on the object-glass of his telescope!

The law which is invoked by the mathematical physicists to explain this first stage in the evolution of a nebula is called the law of the "conservation of momentum," which enables them to forecast the history of any number of particles, moving in any direction, but subjected only to their mutual action. Hence the importance of our argument that the solar system is a thing apart, incredibly remote from the rest of the universe, and that it may be studied without the inextricable complications involved if, from moment to moment, its internal processes were being subjected to outside influences. We may assume that its development would be left to itself, and the laws of mathematics assure us that such development would mean its assumption of the spiral form from its initial chaos.

From Chaotic Nebula to Spiral Nebula the First Stage of World Formation

We know scores of thousands of spiral nebulæ to-day. Probably not less than one half of all the nebulæ we can see are spiral, a notable fact which becomes intelligible in the light of what we have just learnt. The spiral nebulæ constitute, next to the fixed stars, the most important and characteristic objects in the heavens, whether we look at the most recently discovered or at that which Lord Rosse first found, the great nebula in Andromeda, of which a photograph is to be found on page 520.

The spiral nebula, then, constitutes the second stage in the evolution of a system, perhaps of a solar system, and what one may call a "chaotic nebula" constitutes the first stage. The countless gaseous particles of the chaotic nebula are all subject to their mutual gravitational influence. The nebula, therefore, shrinks, just as the sun, the central mass of the original solar nebula, is shrinking at this hour. As the chaotic nebula shrinks, the atoms which compose it tend, in accordance with the law of the conservation of momentum—which we must take on trust from the mathematicians—to arrange themselves in a number of planes.

One of these planes comprises far more of the matter of the nebula than any other, and is called its principal plane. In the course of ages the atoms in these various planes, which are inclined at various angles to each other, attract one another, so that ultimately the

whole substance of the nebula is disposed in one plane, which is, approximately, the principal plane already described. The former chaos, which was perhaps roughly spherical, is thus now resolved into a flat object—like the solar system—nearly all the atoms of which are now revolving in the same direction—like the members of the solar system—around their common centre of gravity, which in our case is the sun.

But there is another most important difference between the chaotic or primitive nebula and the flattened spiral nebula to which it has yielded. For it was shown by Sir William Huggins that the spectrum of a young or chaotic nebula is discontinuous—consisting of bright lines separated by dark intervals—and that thus the chaotic nebula is all gaseous; but he further showed that the spectrum of a spiral nebula is continuous—made of an unbroken band of colours which shade off into one another—and that thus the dense patches which we can actually see in spiral nebulæ indicate places where the nebula is beginning to solidify.

It is rather puzzling that a continuous body of gas should yield a discontinuous spectrum, while, if this body become itself discontinuous, its spectrum becomes continuous; but if once we state the fact thus we shall remember it.

The Theory that Laplace Gave to the World and that Long Held the Field

Now, in the case of many or all of the spiral nebulæ which we can see in the sky, the dimensions are so stupendous and the whole affair is on so huge a scale that we must suppose the denser patches to be incipient stars, like the stars which we see in the nebula in Orion. But in the case of our little system we must suppose that the denser patches, which presumably formed in the spiral nebula whence we come, were not stars, but planets.

We learn, therefore, supported by the researches of the spectroscope, that a spiral nebula is formed of more or less solid bodies—destined to become suns or planets—surrounded by a rarer gas, which ultimately attaches itself to them, so that there is produced a system of revolving bodies separated by empty space—empty but for the presence of the omnipresent ether. This is the present, though certainly not the final, state of our own system.

Now, the classical or orthodox form of the nebular theory, as stated by Laplace, agreed in certain substantial respects with the foregoing. It supposed the matter of the solar system to have existed originally in the form of a vast, diffused, rotating nebula, which, as it gradually cooled and contracted, threw off successive rings of matter, rather after the fashion in which "centrifugal force" throws off the raindrops from a rotating umbrella. Then, according to this theory, the successive rings would resolve themselves into aggregates of matter which, in time, would settle down into planets. We are bound to recognise a past nebular stage in the evolution of the solar system, and we should do honour to Kant and Laplace and Herbert Spencer, to whom we owe this great conception.

How Time and the Mathematician have Corrected the Theory of Laplace

But there are overwhelming arguments against the statement of the theory in the form which we have just described. The mathematicians have devoted long years to the subject, and they show that the breaking off of rings of matter from a rotating nebula, and their coalescence to form spheres, are mathematically impossible. But we should remember that Laplace died in 1827, and Lord Rosse did not even build his telescope until some years afterwards. Laplace never saw a spiral nebula, nor could guess that such things existed. All the greater is the honour due to him for having elaborated his theory; and it is our advantage that we can restate it to day with the existence of spiral nebulæ in our minds, and with the mathematical demonstration that a nebula such as Laplace imagined and argued from would assume the spiral form, which the spectroscope proves to include the presence of more or less solid masses—suns or planets. Time, therefore, would seem to have both confirmed and corrected Laplace.

The Probability of Intense Original Coldness Changed to Heat by Clashing Particles

Many problems are involved in the assumption that the original nebula must cool and contract. The statement sounds satisfactory, especially if we think of the original nebula as a "fire-mist." But there are many questions to settle. On its first formation, which might be by the vast dispersal of a formerly compact body of matter, the nebula might be intensely cold. It would unquestionably contract, because of the force of gravitation; we do not need to assume it to have been hot, and become cool, in order to account for its shrinkage. Gravitation would cause the shrinkage of any such nebula, however cold; and, indeed, the probability is that the first stage of such a nebula as we are considering would be intensely cold.

Whence, then, it will be asked, the present warmth of the sun, or of the interior of the earth? The reply is that the gravitational shrinkage of such a nebula, and the mutual clash of its atoms, would generate heat. The temperature of a nebula might thus rise, from extreme cold, up to any point, even while the nebula contracted. On the other hand, the rise of temperature, if such occurred, would tend to neutralise the contraction of the nebula, for a body expands as its temperature rises, other things being equal. At any rate, it seems clear that we must abandon the idea of the "fire-mist" as being the first stage of the solar or any other nebula. Its first stage must, much more probably, have been exceedingly cold. It was probably, in the beginning, a dark nebula, like many another.

If the critic should find it incredible that from a cold, dark, and far-flung nebula there could be evolved our hot and radiant sun, merely in virtue of the force of gravitation, the answer to the doubt as to this possibility—whatever actually happened—is readily made in the calculations of such illustrious authorities as Helmholtz. For, indeed, the present source of the sun's heat and light and other forms of radiant energy is a great problem; and the best explanation hitherto is that which ascribes these tremendous manifestations of energy to nothing other than this same gravitational shrinkage, which is supposed to have been going on ever since the days when the solar nebula extended beyond the orbit of Neptune.

LAPLACE'S THEORY OF THE NEBULA

Laplace imagined the solar system originating as a vast incandescent nebula that had assumed a rotatory movement. The outer parts moved faster than the central core, and, as the cooling process went on, condensed, as it were, into rings similar to the one seen in this picture. This ring evolved into a planet, and its satellites were formed from it by a process similar to that of its own formation.

It is reckoned that a shrinkage of the sun, due solely to the mutual gravitation of its parts, that amounted to no greater reduction of its diameter than sixteen inches per annum, would account for all the energy which the sun now produces. Plainly, therefore, there is nothing incredible in the more modern view, which looks upon the first stage of the sun, or of the solar nebula of which the sun is the remaining core, as anything but sunny, not at all like a fire-mist, or such a glowing mass of gas as the nebula in Orion, but as a vast, dark, intensely cold, intensely sparse and rare collection—or dispersion—of gas, for which no bright future could well have been predicted. This page, of course, was somewhere there, together with the matter of our bodies, as well as of the sun. Such personal considerations may bring the wonder and interest of this matter closer to us.

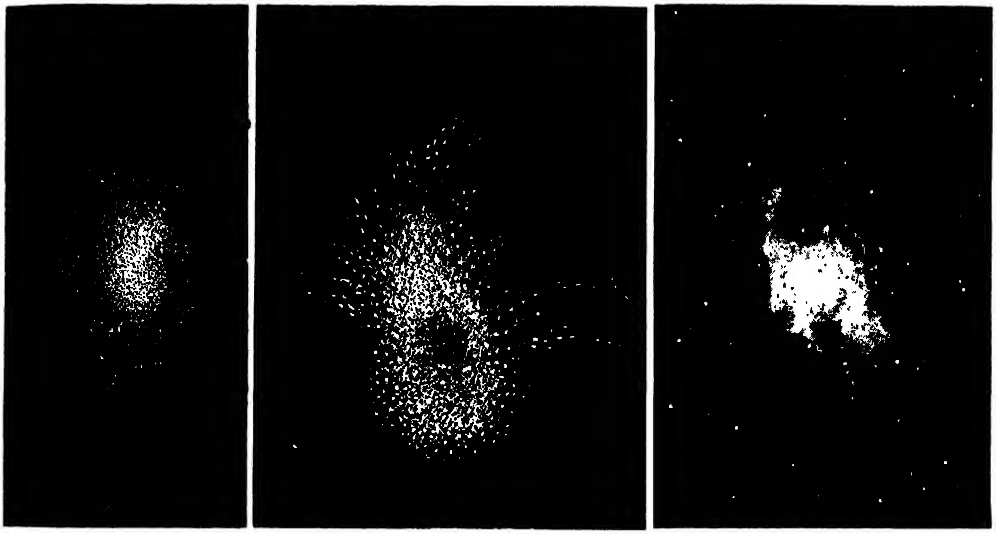
The dark nebula, we have argued, might evolve, by means of gravitation and the laws of motion and momentum, into some such system as ours is to-day, with its bright and sunny core. But the evolutionist is scarcely likely to expect that this state is final, or that "the planetary system, on this scheme, will last for ever." On the contrary, if we continue to consider the working of the laws which have brought the solar system to its present stage, we find that these laws ensure that the planetary system which they have moulded will *not* endure for ever. For here we meet new considerations, advanced by Sir George Darwin, whose illustrious father taught us that species are mutable.

The son now teaches us that the solar system must be mutable also, and subject to the law of universal evolution. In his Presidential Address to the British Association when it met in 1905 at Cape Town, Sir George Darwin, under the title of "Evolutionary Speculation," showed how the evolutionary principle, of which his father was so great a champion in the world of life, must apply to inorganic nature also.

Above all, Sir George Darwin has studied the tides, and has thus been enabled to forecast the future of the solar system. Even at this hour the tides are acting as a brake upon the earth as she rotates; and though no estimates of this action are worth more than the particular assumptions on which they are based, we may note that, at one time, Sir George Darwin reckoned that the retarding influence of the tides might delay the earth's rotation

to the extent of twenty-two seconds' loss in the course of a century. The tides upon the earth are at present produced mainly by the gravitational action of the moon. We do not need to decide whether the moon was formed from the earth in one way or in another, but we are certain that the present relation of the earth and the moon has not always been so; and the present effect of the tides must be, as we have said, slowly but surely to lengthen the day. We may expect that this process, already long in progress, will continue until eventually the moon and the earth rotate together, as if a solid bar ran between them. The month and the day will then be equal, and there will be no moon-raised tides upon the earth. But even if we ignore the influence of the other planets, there will still be sun-raised tides upon the earth, and tides upon the sun raised by the earth, or the earth-moon system, just as Jupiter raises tides upon the sun now. Just as the tides upon the earth check its rotation, so the solar tides must check the rotation of the sun. But these alterations in the rate of rotation of the earth and sun, as also of other planets, must lead to what may truly and literally be called momentous consequences. We have already referred to a certain law, of the conservation of momentum, which, the mathematicians tell us, has already had important consequences in the shaping of our system. According to this law, there must be present in our system, if it be left untouched by outside agencies, a certain definite quantity of what is very clumsily called "moment of momentum"; and whatever happens in the solar system, that quantity must remain constant. If, therefore, the earth or the sun lose some of the momentum of their rotation by the action of the tides, other compensatory changes must occur, so that the "moment of momentum" within the solar system may remain unchanged.

Such, in outline, are the foundations which have led Sir George Darwin to predict that the moon will ultimately return to the earth, whence she somehow must have come many ages ago; and from these and other considerations, including the recently discovered force of radiation-pressure, which must check the flight of the planets in their orbits, thus comparing with the action of tides upon the rotation of the planets, it may also be predicted that the planets and their satellites must ultimately yield to the gravitational influence of the sun and return to the bosom of their parent. Thus the solar system of to-day would have become gathered into one central mass, closely aggregated around that point which, from the first, has constituted its centre of gravity. What, now, will be the state of things?



THE GROWTH IN OUR KNOWLEDGE OF NEBULÆ—THE CRAB NEBULA, AS VISUALISED EIGHTY YEARS AGO AND TO-DAY

These three pictures illustrate the growth of our knowledge of nebulæ in the last hundred years. On the left we have the Crab nebula as it appeared to Sir John Herschel about 1830. The centre picture shows the same nebula as it appeared through Lord Rosse's telescope about 1850, resembling rather a star-cluster than a nebula, and in consequence so reclassified. In the modern photograph on the right, taken by Mr. G. W. Ritchey, we see that it is really a nebulous mass.

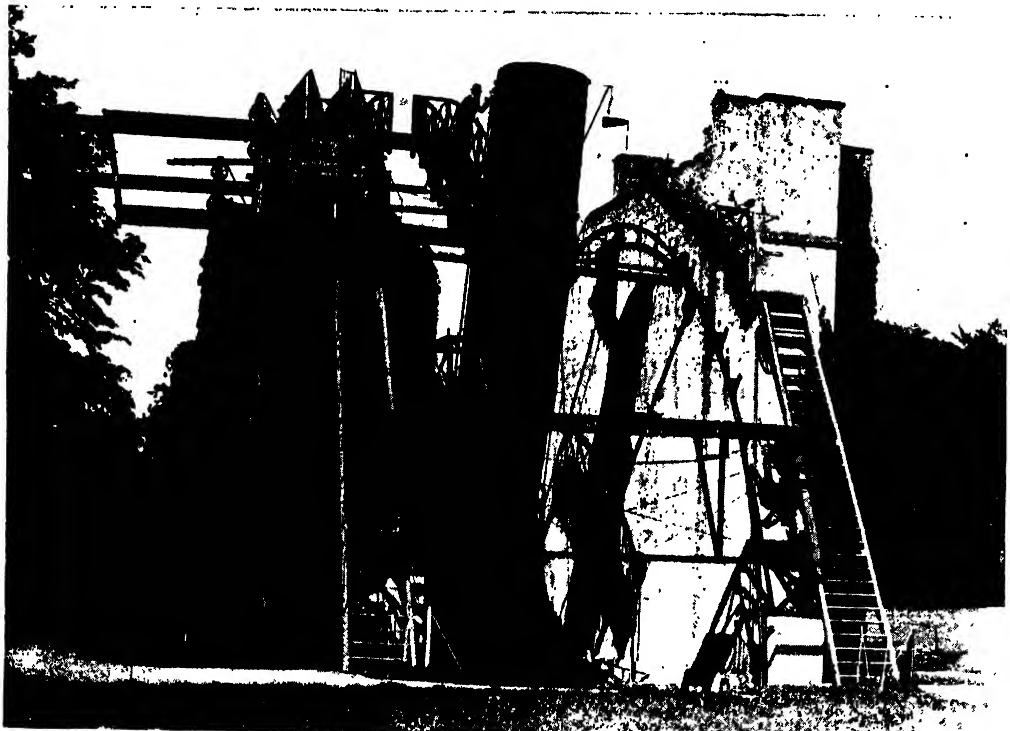
The dark nebula with which we began will have become resolved into a dark star — the course of the solar system, and of the human race, to name no other, having been run in the interval. There are doubtless millions upon millions of such stars in the heavens at this or any other time. This dark future tomb of the bodies of all that now live, and have lived, and will live will therefore be just such another as many millions more. There will then be no possibility, upon any part of it, of any life at all. We must believe that its cold would be intense, for the solar nebula that was will have been steadily dissipating energy, in the form of light and heat, into the chilly depths of space, ever since its age-long shrinkage began.

It seems a hopeless consummation—until we remember that there is no finality in the universe; that change, as we have said, is its most deeply rooted habit, and that the very causes which require the ruin of our solar system will still be in action. This dead sun of the future is not for ever to be borne desperately onwards through infinite space, "stable in desolation." In this dynamic universe, desolation can no more be stable than the heyday of life and joy. This dark and cold and shrivelled globe, the common tomb of sun and earth and moon and Mars, and of the bodies of the great that once breathed thereon, may live again. Give it but the consummating embrace of such another voyager, and in a moment a new nebula may be born.

Observe that the laws of gravitation and motion and energy *go on acting*. They seem to build in order to destroy; but they can rebuild, and do. Gravitation would be at work between this dead sun and all the other bodies in the universe. A collision is therefore not only likely, but perhaps sooner or later inevitable. And then the laws of energy will show their power. No energy can be destroyed.

If the motion of two dark suns, for instance, is in great degree arrested by a collision, it must take some other form, for destroyed it cannot be. The force of impact might well suffice to reduce the matter of these suns to a hot gas which, in virtue of its heat, would expand—almost with explosive violence.

Hence a nebula, spread out, and intensely cooled by its expansion, as is the rule with gases—the energy of their heat



THE FAMOUS TELESCOPE, ERECTED BY LORD ROSSE AT BIRR, IRELAND, WHICH REVEALED NEW ASTRONOMICAL KNOWLEDGE IN THE MIDDLE OF THE NINETEENTH CENTURY

From a photograph by W. Lawrence, Dublin.

being transformed into the energy which spreads them out.

This nebula might be at first chaotic in form, or it might already be disposed so as to have a "principal plane," such as we argued in an early stage of the formation of the solar system. The explanation of the existence of this principal plane would be a dark and chaotic nebula, or, if not necessarily either quite dark or quite chaotic, at least a nebula. We were entitled to ask its origin, but we preferred to accept it and trace its probable destiny. And now, it would appear, the last stage of this nebula indicates the origin of its first stage. For it may well be that the nebula from which the

A NEBULA IN THE CONSTELLATION OF COMA BERENICES THAT APPEARS EDGEWISE TO THE EARTH

In this photograph, taken by Mr. G. W. Ritchey, we see a nebula in a stage that throws considerable light on the evolution of our own solar system. The condensed white core which will become the sun of the system is seen to be the centre of a mass revolving in a plane, the outside edge appearing darker by contrast, owing to the cooling process that is going on.

that it corresponded to the path of the two dead suns, thus reborn. This principal plane would then serve to form the ground plan, so to say, of the new system—a system new in time, alien in place, yet in large part composed of the same imperishable substance as the old.

Thus, in the theory here set forth, the wheel has come full circle. We began with solar system is formed was itself produced by the impact, and composed of the substance, of two or more bodies, each of which may well have been the dark epitome and consummation of a system such as ours. Would it not appear that, if we want a great measure of time, an *annus magnus* such as the ancients fabled, the mighty interval from the formation of one nebula to its

phœnix-like end in another, might furnish us with the stupendous unit that we are in search of? With such a unit, and yet utterly without success, we might try to measure eternity. The rhythm of universal history, the strides of the eternal, are from nebula to nebula.

"And we," to quote a recent commentator, "ephemeral dwellers on the doomed satellite of a dying sun, we to whom a scroll so endless has begun to be unfolded, how does it all strike us as, from our standpoint between two nebulæ, we survey the Cosmos of which our physical substance is, if an ephemeral, yet an inalienable, imperishable part? For our bodily substance has a past how long and glorious, a future how fraught with possibility! The atoms in the tear wherewith your winking eyelid has just now, for its benefit, moistened your eyeball, where were they when the solar nebula reached out beyond Neptune?

The Eternal Cyclic Course of Sentient Life an Epic Indeed

"The fact of the conservation of energy teaching us that there shall never be one lost iota of power, nor ever has been—considered with the nebular theory, which teaches us afresh and in the authoritative tones of mathematics the lesson of Heraclitus and Herbert Spencer, that the Cosmos pursues an eternal succession of cyclical changes—reveals to the imagination a vista of sheer sublimity. Surely the reader, accepting the vision of matter and energy, eternally indestructible, eternally pursuing this cyclic course, and ever and again giving rise to sentient and reasoning creatures such as himself, may agree that here is an epic indeed."

The preceding theory is clearly and essentially that of the origin of the solar system in a nebula, which is, in its early stages, a gas. We must later consider other aspects of our question, but meanwhile this is the statement of a nebular theory. It is certainly not "the nebular theory" of Laplace, though it owes its genesis to him. Theories evolve, like all things else. The primitive stage of the nebular theory has evolved, under the influence of further knowledge, which has compelled us to reject the idea of a rotating disc-like nebula, from the whirling edge of which successive rings were detached, each in its turn to resolve itself into the sphere we call a planet. A whirling disc would not detach rings of its substance in this fashion, nor would the substance of such rings come together in the fashion supposed. The process sounds plausible at the first hearing, but the difficulties of realising it are quite insuperable. Something else is required, and the discovery of the spiral nebulæ, after Laplace's death, helps us to advance his theory and to present it in a new form, such as that which we have here stated.

The Age of a Planet Determined by its Size Rather than Date of Formation

Be it noted that the comparative age of the planets comes into this question. On the classical form of the nebular theory, the first planet to be born would be the outermost —Neptune, if he be the outermost. As the nebula shrank, successive rings of matter would indicate the former positions of its edge, and the sequence of the sun's family would be from the outermost planet to the innermost. Let us carefully observe, lest future study of individual planets appears to involve us in contradiction, that to discuss the age of a planet, and to discuss the rate of its development, are quite different things. We are here considering only the order of formation of the planets. The fact will remain, quite independent of this, that different planets must undergo their individual evolution at different rates, mainly in dependence upon their size. Thus the giant Jupiter is still hot, and perhaps even glowing, while our little moon, which was only formed yesterday compared with Jupiter, is already old and dead.

But so far as the actual dates of first formation of the planets are concerned, the nebular theory in its original form, if not in the considerably modified form which we have here presented, would involve, apparently, the successive birth of the planets in order from without inwards, though their individual rate of development may vary, as among the members of other families.

The Meteoritic Theory of Origin of Planets Held by Sir Norman Lockyer

We are, nevertheless, required to remember that there are other theories of the origin of the solar system, and especially of the formation of the individual planets; and it might be that the order of their formation was quite different from what, on the simpler form of the nebular theory, would be required. If we look at spiral nebulæ now in the skies, and remember that the modern form of the nebular theory requires a spiral stage, we may see that the successive formation of solid bodies in a spiral nebula from without inwards is not required, and does not find any warrant in the actual appearance of the spiral nebulæ we can see. The statement of the order of birth of the planets, which depends upon the

original form of the nebular theory, must therefore be abandoned. But not yet shall we be able to state what their order of birth really has been.

Lest confusion supervene later, let us realise that the foregoing theory is definitely that of a gaseous nebula; and we have suggested that the substance of the meteorites we know to be part of our present system must have been in that nebula. Here is a sharp contrast to a recent view of the origin of the solar system which we owe to Sir Norman Lockyer, and which is called the "meteoritic hypothesis." This theory begins not with a collection of gas, but with a multitude of meteorites, which are solid bodies; and it argues that such meteorites might become aggregated, perhaps with clash and heat and gas formation, so as ultimately to form planets. On this view, present meteorites, so far from having, so to say, crystallised out of the original nebula, would be simply those "left over" when the planets were formed.

A SO-CALLED DARK RIFT IN THE MILKY WAY

The dark parts in the brilliant mass of stars that form a girdle in the heavens are believed by some to be caused by dark nebulous masses that obscure the stars behind them. Colour is lent to this theory by the fact that in this photograph, taken by Mr. E. E. Barnard, some of the brighter stars seem to penetrate through the least dense parts of the supposed dark nebula.

Obviously the two theories are very different, and we can make no progress unless we keep them distinct in our minds. What is here stated is a theory which starts neither with meteorites nor, as another theory does, with very small planetary bodies, already in revolution round some larger body, but with a true gaseous nebula. If, as we may afterwards find reason to suppose, many or all spiral nebulæ consist of tiny solid bodies, plainly there may be some possibility of combination between our present theory and that which asserts a stage of myriads of such bodies; but, meanwhile, any theory that starts with a body of gas and ends with such a body is properly to be called a nebular theory, and dates from Lucretius, Kant, and Laplace.

Lastly, we may be asked how long, in what may almost be called human years, these changes would take. We have suggested that the *annus magnus*, one wave-length of the great vibration of things, would be from a nebula just formed to another such nebula just formed. What would be the measure of its unit in terms of our earth's little journey round the sun? No one can presume to answer these questions. We are in the realm of speculation, where no two astronomers agree, yet where it is right that the mind should travel, though there be no goal, to go is goal enough. But at least we can reckon the periods involved on the basis of this or that set of assumptions; and the answer is that such estimates run from scores of millions of years upwards.

The earlier estimates are the shorter. Every new advance in knowledge extends our conception of what may perhaps be called an inter-nebular period. No one now living would accept the estimates of Kelvin or Helmholtz. When we study the sun we shall find that we are also studying this very question. Meanwhile we may at least confidently state that the lowest possible estimate of the life of our nebula must be not less than many hundreds of millions of years; and in a few more of such little years we shall be saying not "hundreds" but thousands. Yet we need not cower, as if the mind were thus dwarfed by what it figures. Can the mind be less great than its own conceptions?

HAS RADIUM HELPED TO BUILD BATH?

It has been suggested that the curative value and the warmth of the waters of Bath are due to emanations of radium far down in the crust of the earth. Examples are given above of deposits in Bath waters that are believed to be radio-active. The photograph, by Messrs. Lewis Bros., of Bath, shows a deposit found on a pillar, two stalactites on the right, and sand in a glass, all with traces of radio-activity

THE RADIO-ACTIVE ELEMENTS

How They Were Discovered; How We Estimate Their Age and Quantity; and How New Elements are Born

BREAKING UP THE "FOUNDATION STONES"

In the last chapter we described some of the marvels of the vacuum tube, but a very sensational discovery leading to discoveries even more sensational is still to be described.

In 1895 Professor Röntgen, of Munich, noticed that if photographic plates were left in the neighbourhood of a vacuum tube traversed by an electric current, they became fogged even if kept under cover; and when he proceeded to investigate this matter he found that from the tube there issued rays which had the power of passing through various solid substances, such as paper, wood, skin, and leather. By means of these rays he was actually able to photograph the bones of the living body.

The rays were at first a great puzzle, but now their origin and nature have been fully worked out. They are produced whenever corpuscles impinge on any solid body, such as the glass of the vacuum tube, and they fly as fast as light—namely, 185,000 miles a second. They are certainly light-waves, but waves shorter even than the waves of ultra-violet light, and they seem irregular instead of periodic. Like the negative corpuscles, they cause certain substances, such as barium-platino-cyanide and calcium-tungstate, to phosphoresce.

This property of causing phosphorescence is turned to useful account by means of a screen coated with a phosphorescible substance. If a hand be held between such a prepared screen and X-ray light, the light will shine through the flesh of the hand, but will be unable to penetrate the denser bones, and hence the bones will be seen in shadow on a phosphorescing background. So, any object partly transparent and partly opaque to the rays will give a picture in light and shadow. In this way it is possible quickly to detect fractures and dislocations, and to discover needles, bullets, or other bodies in the deeper tissues of the human body. It is possible even to watch the heart beating and the diaphragm moving up and down. Of course, the phosphorescent pictures are transient, and if permanent records are required it is necessary to take photographs.

The production of phosphorescence by the X-rays led indirectly to the discovery of radio-active elements. The story of this discovery—perhaps the greatest discovery of the nineteenth century—is quite a romance, and it is also an interesting example of the way in which chance and skill work together in scientific progress.

Even before the discovery of X-rays it had been known that the phosphorescent light given off by calcium sulphide, after exposure to sunlight, had the power of penetrating metals; and Henri Becquerel, the famous Professor of Physics in Paris, knowing this, began to make experiments with various phosphorescent—or, rather, perhaps we should say phosphorescible—substances to discover whether the penetrating capacity of the X-rays was of a phosphorescent character. "For my part," he says, "from the day on which I first had knowledge of the discovery of Professor Röntgen, there came to me, too, the idea of seeing whether the property of emitting very penetrating rays was not intimately bound up with phosphorescence."

One day in the course of his experiments he laid a bit of uranium on a photographic plate covered with black paper. On subsequent examination he found that rays from the uranium had penetrated the black paper and had affected the photographic film. There was nothing very amazing about that. Other substances when exposed to light were known to have the same faculty. But quite a new and astounding aspect was given to the case when Becquerel discovered that uranium gave off these rays spontaneously, of its own accord, without any

exposure to sunlight. At first he had thought that it was necessary to expose the substance to penetrating rays of sunlight, but soon he recognised "that the emission of the rays was produced spontaneously, even when the substance had been kept completely sheltered from any previous exposure to light."

The difference between rays spontaneously produced and rays provoked by the energy of the sun may not seem great, but it is as great a difference as would subsist between a watch wound up daily and a watch able to go without any winding up at all—nay, a far, far greater difference than this, for, as we shall see later, the energy stored up in a little uranium is greater than the energy in all the wound-up watches of the world. It was in 1896 that Becquerel made his great discovery, and his historical piece of uranium is still radiant, and shows no diminution in its radiancy.

Soon after this discovery of Becquerel, the late Pierre Curie, Professor of Physics in the School of Physics and Industrial Chemistry in Paris, and his wife, Madame Curie, discovered that another element, thorium, was also radio-active, and noticed that minerals containing uranium were more radio-active than uranium itself. The fact that uranium minerals were more radio-active than uranium itself naturally led to the surmise that the minerals must contain some substance or substances more radio-active than uranium.

The Epoch-Making Discovery of a French Scientist and his Polish Wife

Obtaining a ton of uranium residues from the State manufactory at Joachimsthal, Bohemia, they proceeded to search for these substances. And they found them. They found two more remarkably radio-active substances. One they named *polonium*, after Poland, the native land of Madame Curie; the other they called *radium*. The Curies announced their great discovery in the following words, "We have, in fact, been able to prove that it is possible by the methods of ordinary chemical analysis to extract, from pitchblende, substances of which the radio-activity is in the neighbourhood of 100,000 times greater than that of the metal uranium."

The patience and skill required to extract the radium was prodigious. There is only one part of radium in three million parts of the uranium mineral, and from a whole ton of it the Curies obtained only four or five grains of radium. At present there are only a few grains of radium in the world, worth many thousand times their weight in gold.

Soon after this remarkable discovery of the Curies, Debierne found still another radio-active body now, called *actinium*. There are thus at least five radio-active elements known to us: uranium, thorium, radium, polonium, and actinium.

The radio-activity of radium has been carefully investigated, and it is known that the radiations are of three kinds.

The Three Different Radiations that have been Found to Emanate from Radium

1. Alpha rays, so-called, which consist of particles about twice the size of a hydrogen atom, charged with positive electrity, and projected at a rate of about fifteen thousand miles a second. They have small penetrating power, being stopped by a layer of aluminium about $\frac{1}{2500}$ of an inch in thickness. They can be deflected by a magnet, but only to a small extent.

2. Beta rays, which consist of corpuscles like the corpuscles in a vacuum tube. They are charged with negative electricity, and are projected at rates varying from 75,000 to 170,000 miles a second. They will penetrate a layer of aluminium about one-fifth of an inch thick, and they are deflected by a magnet.

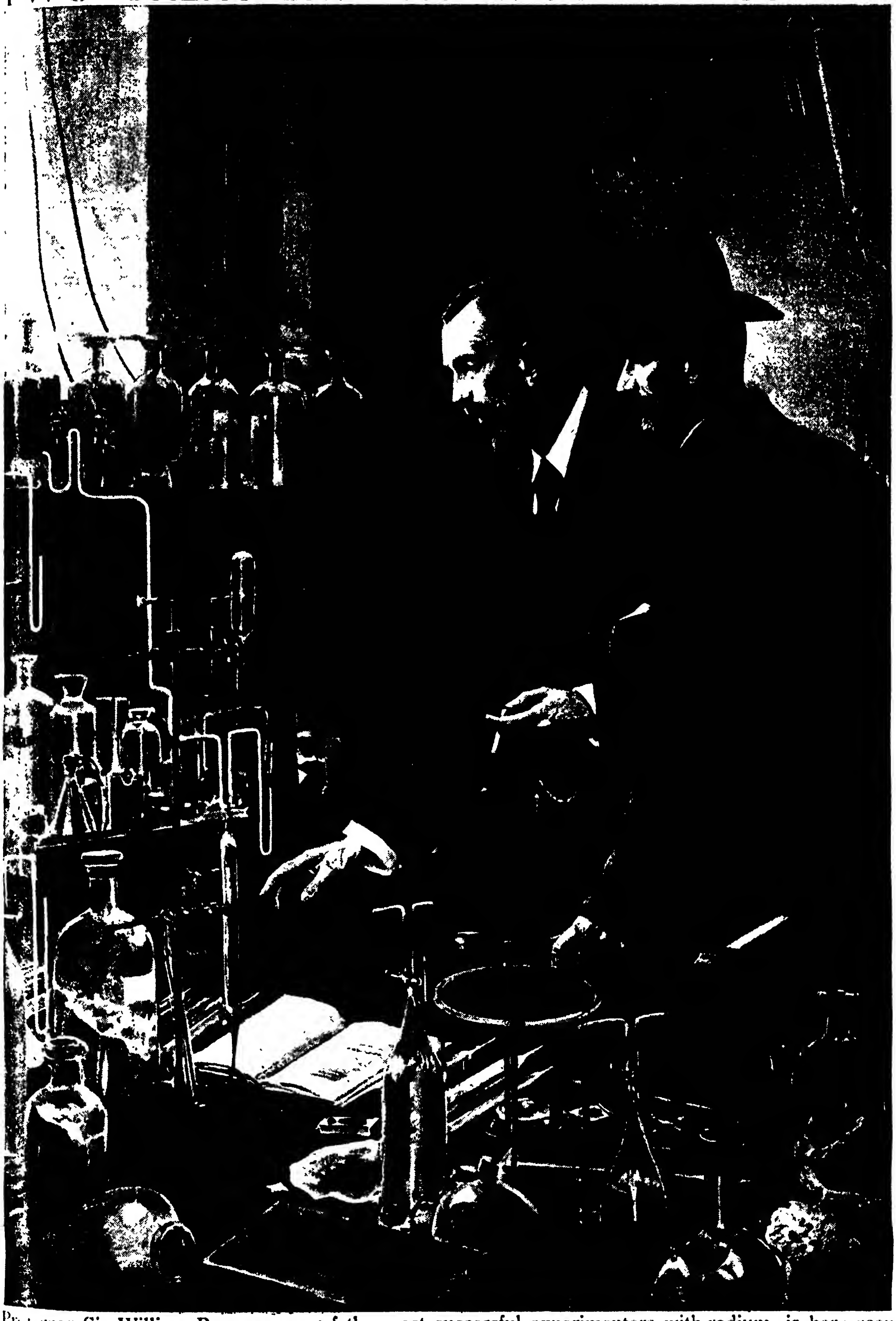
3. Gamma rays, which resemble in many respects the X-rays. These rays have great penetrative power; they will traverse a plate of aluminium twenty inches thick, or a plate of lead nearly three inches thick.

All the rays—alpha, beta, and gamma—affect photographic plates, discharge electrified bodies, and excite phosphorescence in certain substances. If a tiny pinch of radium be fixed in front of a plate covered with zinc sulphide, and the plate be viewed in the dark through a magnifying lens, the zinc sulphide will be seen to scintillate, and emit tiny sparks under the bombardment of the alpha rays. The appearance is that of a swamp full of "fireflies, or of scintillating stars on a dark night." Sir William Crookes has invented a neat little instrument called a spinthariscope, which exhibits these sparks. Not only does radium excite phosphorescence, but it is itself phosphorescent, so that it can be photographed by its own light.

The Extraordinary Developments that Followed from a Further Study of Radium

But all this was merely a prelude to still more wonderful and suggestive discoveries. It was soon further found out that radium rendered all objects in its vicinity radio-active. This acquired radio-activity lasted for hours or days, even after the radium had been removed, and was shown to be caused by a vapour-like emanation which diffuses

TWO GREAT EXPERTS IN SCIENCE CONFER



Professor Sir William Ramsay, one of the most successful experimenters with radium, is here seen in conference with the late Professor Pierre Curie, of Paris, who, in collaboration with his wife, Madame Curie, was the discoverer of radium.

slowly through the atmosphere from the radio-active substance, and which formed a deposit on surrounding objects and rendered them radio-active.

The emanation behaves in most respects exactly like a gas; it diffuses like a gas; it gives a spectrum resembling the spectrum of the inert atmospheric gases; it can be carried along by a current of air, and it can be condensed from the air by extreme cold. It can be obtained most readily by dissolving a little radium chloride in water. Then when air is passed through the solution the air becomes laden with the emanation, and can be kept in an ordinary gas-holder. Air so laden with emanation will illuminate a screen covered with zinc sulphide for days. When the emanation has been washed out of the radium, the radium loses seventy-five per cent. of its radio-activity, and instead of emitting all three rays emits only alpha rays.

Now, what is the nature of the radio-activity of the emanation? What kind of rays does it emit? It emits only alpha rays—that is to say, particles having twice the mass of a hydrogen atom flying with a velocity of about 15,000 miles a second. Having given off these particles, it becomes changed into a solid substance known as radium A. Radium A gives off more alpha rays, and is changed into radium B. Radium B emits no rays, but rearranges itself into another solid, radium C, which gives off alpha, beta, and gamma rays, and becomes transformed into radium D. Radium D, like radium B, emits no rays, but changes into radium E_1, which is also rayless. Radium E_1 changes again into radium E_2, which gives off beta and gamma rays, and is converted into radium F, which gives off alpha rays. It is the radiums A, B, C, D, E_1, E_2, and F that form the radio-active matter deposited by the emanation on any objects it reaches, and which form the main source of the radio-activity of the radium itself.

A KEY AND A COIN WITHIN A PURSE PHOTOGRAPHED BY RADIUM RAYS

The transformation of radium thus proceeds by stages, and most of the stages are the result of explosions with loss of particles. Thus radium atoms throw off alpha particles, and the atoms become the gaseous emanation; radium C atoms fire off alpha, beta, and gamma particles, and the atoms become radium D atoms; radium E_2 atoms shoot off beta and gamma shrapnel, and become radium F. It is a progressive explosive dissolution of the original radium atom.

It has been calculated that radium is breaking down at such a rate that in 1760 years half of it is disintegrated; and at this rate, even if the earth had been originally composed of pure radium, there could not be so much still remaining after the millions of years the earth has existed. How, then, are we to explain the continued occurrence of radium in spite of its decay during millions of years?

The only possible explanation is that radium has not only been broken down, but has been continually produced. And it seems certain that the radium has been produced by the breaking down of the radio-active element uranium, which is continually shooting off particles and undergoing transformations. We are led to this conclusion chiefly by the fact that radium is always found in largest amounts in uranium minerals, and that there is a nearly constant ratio between the amount of uranium and the amount of radium—that is, about 333·3 milligrams of radium to a ton of uranium. But, in addition, experiments have been made that prove that radium reappears, though very gradually, in uranium solutions from which all radium has been removed.

The changes whereby uranium is converted into radium are not fully known, but uranium, losing alpha particles, becomes uranium X, and uranium X shoots forth beta and gamma particles, and becomes finally, probably after several changes, converted into radium.

Though all the stages between uranium X and radium have not been worked out, the direct parent of radium has been found, and has been named ionium. It expels alpha corpuscles of very low velocity, and is transformed thereby into radium.

It is probable that radium F is identical with the radio-active substance which Madame Curie discovered and named polonium. Polonium expels only alpha particles, but it is intensely radio-active—several times as radio-active as radium. A

little speck will cause a diamond to phosphoresce brilliantly, and will so increase the electric conductivity of the air that if brought near an electric bell it will cause it to ring.

Let us now glance for a moment at some of the mathematical aspects and measurements of radio-activity.

Radio-active substances consist of a multitude of atoms more than the sands of the seashore in number; and when they break down, or disintegrate, the process proceeds piecemeal at a regular rate according to a strict mathematical law. In any amount of breaking down atoms become fewer, but they still are the same proportion of the total.

It is plain, since the disintegration of the atoms follows this law, that some of the atoms must live very much longer than others: and in order to get a working constant it is necessary to find the *average* life of the atoms. By a simple mathematical calculation the average life is found to be the reciprocal of the fraction which represents the proportion of disintegrating atoms—that is to say, it is expressed by the fraction

RAYS THAT SHINE THROUGH FLESH—A RADIOGRAPH OF A COIN IN A CHILD'S THROAT

any radio-active substance a certain fixed proportion of the atoms are breaking down, and this proportion never varies. If we know the proportion of atoms that are breaking down now, we know the proportion a million years ago. In the case of the emanation of radium, for instance, 1-500,000th of the total amount of radium emanation is breaking down per second, and this proportion of the whole has been breaking down per second since the emanation was first produced. As the radium emanation becomes less the number of turned upside down. In the case of radium emanation the fraction representing the proportion of disintegrating atoms is $\frac{1}{500000}$, and this turned upside down is 500,000. The average length of life, therefore, of an atom of radium emanation is 500,000 seconds, or 5·3 days. Between the average length of the life of an atom of any radio-active substance, and the time required for the disintegration of half the radio-activity of a substance, a simple and constant ratio subsists. And the average life of the atoms of any radio-active substance can be found by

multiplying by 1·45 the time required to halve its radio-activity.

Thus by observation we find that the radio-activity of radium A falls to half its initial value in three minutes, and by multiplying 3 by 1·45 we get 4·35 minutes as the average life of its atoms.

These are themselves interesting mathematical facts and laws, and on them is based the most important law in the science of radio-activity, the law that if there be two radio-active substances A and B, B being a product of A and disintegrating more rapidly than A, then these two substances will occur in quantities directly proportional to their respective average lives. From this law we can deduce the age of uranium and many other important facts.

From a consideration of the amount of emanation produced by radium, Professor Rutherford concluded that 1-2500th of radium changes into emanation annually, which means, as we have seen, that the average life of the radium atoms is 2500 years. But radium is a product of uranium, and is much more radio-active, and therefore the relative quantities in which radium and uranium occur will indicate their proportional ages. Now it has been found that there are three million parts of uranium to every one part of radium, and, accordingly, the average life of uranium atoms is three million times that of radium atoms, or 7500 million years.

In the case of all radio-active products this ratio is found. If we know the average life of the atoms of any two genetically related radio-active products we know the proportional quantities in which they occur; if we know the proportional quantities in which they are found we know the relative average ages of their atoms.

Thus, if we know that the average life of polonium atoms is only one-four-thousand-six-hundredth that of radium atoms, we know that there must be 4600 times more radium than polonium. Or, if we know that there is found in minerals nine times as much of radium B as of radium C, we know that the atoms of radium B have nine times the average life of the atoms of radium C. The following table, given by Mr. Frederick Soddy, the lecturer on radio-activity at Glasgow University and formerly assistant to Professor Rutherford and to Sir Wm. Ramsay, shows clearly this relationship between quantity and average life of all the transition forms existing as products of uranium in a mineral containing one ton of uranium:

NAME OF SUBSTANCE	PERIOD OF AVERAGE LIFE	QUANTITY IN MILLIGRAMS
Uranium ...	7,500,000,000 years	1,000,000,000 (= 1 ton)
Radium	2500 years	333·3
Emanation ...	5·3 days	One five-hundredth
Radium A ...	4·3 minutes... ...	One millionth
Radium B ...	38 minutes	Nine millionths
Radium C ...	30·5 minutes ...	Seven millionths
Radium D ...	17 years	2·3
Radium E_1 ...	9.5 days	About four thousandths
Radium E_2 ...	7 days	About four thousandths
Radium F (Polonium)	203 days	One fourteenth

These changes and transformations and their laws may seem rather complicated, but their significance is as simple as it is startling: they signify, each and all, a disruption of atoms, resulting in the birth of other atoms of smaller atomic weight, and with new characters. The uranium atom in the course of its breakdown into radium loses 6 or 7 per cent. of its weight, for the atomic weight of uranium is 239, of radium 224. It seems probable that the radium atom breaks down until it reaches an atomic weight of 207, when it becomes lead. We are witnesses, therefore, not only of the breaking down of atoms such as we have seen every vacuum tube shows, but of the actual birth of new elements through the disruption of the old.

Some of the new elements such as thorium emanation last only a few seconds, some such as uranium last for more than a thousand million years, and some last a thousand times as long as uranium, and seem eternal. But in the light of such transmutation and disruption as we already know, and of the fact that all elements are composed of the same primary matter, it is certain that durability is merely a question of degree. The heavier atoms containing the most numerous corpuscles break up most readily—radium, thorium, actinium, uranium, have all high atomic weights—but even the lighter elements are mortal and frangible.

It is probable that the original radio-active minerals were deposited on the surface of the earth thousands of million years ago, and that they have been undergoing transformation ever since. It is probable, too, that they were formed in the depths of the earth, where heat and pressure would favour the formation of heavy atoms; and it is quite possible that radio-active matter may still be in formation in the bowels of the earth, and that radio-active processes may be going on whose heat will eventually radiate outwards and flux the surface rocks of the world.

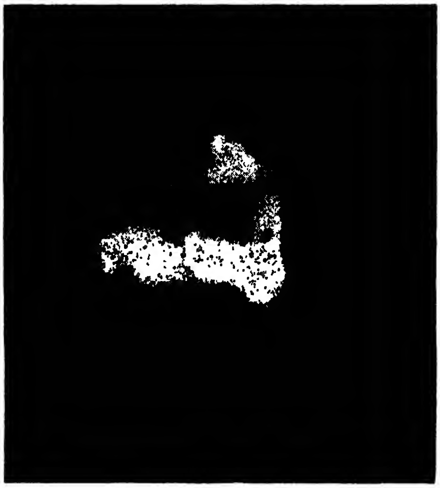
GRAINS OF RADIUM FROM TONS OF REFUSE

In the above photograph Dr. Alfred Gradenwitz shows the machinery employed in experiments, lasting several months, to extract radium from pitchblende residue. One or two milligrams of radium to a ton of residue is considered a satisfactory yield.

Seeing that we now know that the more massive atoms break down into less massive ones, it may be supposed that all the atoms are the product of one original heavy atomic parent, but we have no proof of this; and, indeed, we have no reason to preclude the other possibility that some of the big, heavy atoms have been built up from smaller, lighter ones.

One of the most interesting of the half-solved problems raised by radium is the relationship between the alpha rays it discharges and the remarkable gas called helium. Helium was discovered first in 1868 in the spectrum of the sun, and was afterwards found in certain stars, but for nearly thirty years no sign of it was found on the earth. In 1895, however, it was detected in minerals containing uranium and thorium. It is a light gas, only twice as dense as hydrogen, and will combine with no other substance, in this last respect resembling the inert gases of the atmosphere.

In 1902 Rutherford and Soddy made the very interesting suggestion that the alpha particles thrown off by so many radio-active substances were atoms of helium, or, in other words, that the gas helium consisted of certain fragments of disintegrating atoms. Weight was lent to this theory by the facts that the alpha particles and the helium atom had both twice the density of the hydrogen atom, and that helium was found in all radio-active minerals. Two years later experiments proved that helium was actually produced by radium, and there seems no doubt that alpha particles and helium atoms are identical. As Rutherford remarks: "The discovery of helium by the radium emanation was of great importance, as it showed in a striking manner the extraordinary nature of the processes occurring in radium, and was the first definite evidence of the possibility of one element being transformed into another stable element."



CORNISH PITCHBLENDE RADIOGRAPHED BY ITS OWN EMANATIONS

This radiograph and those on pages 1150 and 1151 are by Mr. F. H. Glew

It is very interesting to notice that every ejection of an alpha particle lowers the atomic weight of the new product by four, which equals the atomic weight of the helium atom.

Since we can roughly estimate the rate of production of helium by radio-active minerals, it should be possible roughly to determine the minimum age of any radio-active mineral by a consideration of the amount of helium it contains. Estimated by this method, the age of certain uranium minerals obtained from Connecticut was found to be not less than 500 million years. Probably when the data for calculation are more accurately ascertained, this method "will prove one of the most reliable methods of determining the age of the various geological formations." An even more reliable estimate might be made from the percentage of lead, for the lead, once formed, cannot escape. So far, however, it has not been actually proved that lead is a product of radium.

It might be thought, since a radio-active substance is presumably a substance in a comparatively unstable state, that it would be possible by physical or chemical means to hasten or retard its disintegration, but this is not so: we cannot control the radio-active process in any way. It is not influenced by heat or cold, or chemical agency. Even the intense cold of liquid air does not affect the radio-active processes.

Very soon after the discovery of radium it was discovered that the air contained radio-active substances; and by means of a negatively charged wire it was found possible to collect radio-active matter from the air, capable of affecting photographic plates and of producing phosphorescence. Soil, too, especially clay soil, was found to be radio-active, and air sucked up from the surface soil was found to have abnormal radio-activity. Likewise water from deep wells and springs contained considerable amounts of radio-active matter; and it is possible that the medicinal value of hot springs such as those of Bath and Buxton depend on their radio-activity. The water of hot springs rising from great depths is

always specially radio-active. Even petroleum from a deep well has been shown to contain radium emanation.

The radio-activity of the soil is due to small quantities of radium, thorium, and actinium emanations, and the radio-activity of the atmosphere is due to the escape of the emanation from the soil, and varies with barometric pressure and other meteorological conditions. It has been estimated that about 600 tons of radium must be in the superficial soil in order to keep up the supply of radio-active matter in the atmosphere; and, as we have stated in an earlier chapter, there is probably enough radium in the crust of the earth to maintain its heat in spite of constant leakage.

MINERALS CONTAINING RADIO-ACTIVE SUBSTANCES PHOTOGRAPHED BY THEIR EMANATIONS

This photograph, by Sir William Crookes, O.M., F.R.S., shows the result obtained by placing a number of minerals containing radio-active substances on a photographic plate in darkness for nineteen days. These minerals are: A, thorite; B, torbernite; C, autunite; D, uranite; E, uranium ore; F, pitchblende; G, alvite; H, arrhenite; J, euxenite; K, chalcolite; L, broggerite; M, yellow wückit; N and O, black wückit; P, samarskite; and Q, fergusonite.

It is possible that the curative effects of certain mineral springs may be due to the radio-activity of their waters, but little is really known of the physiological effect of the radiations of radio-active substances. We know, however, that if the skin be exposed to the bombardment of radium rays, sores appear after a few days which are very difficult to heal. Caterpillars, too, and other small creatures are killed if they are shut into a small box along with a small quantity of radium.

One effect of the radium is probably to coagulate the proteids of the living body. If a solution of globulin, a proteid found in the living tissues, be exposed to alpha rays it is immediately coagulated.

THE TIRELESS ACTIVITY OF THE CELL

This microphotograph of the growing point of a pine-branch, enlarged some eighty thousand times, shows the tremendous activity that goes on in the cell-production that we call growth. The cells that form the mass of tissue at the tip of a branch are continually dividing up to form others. Some cells remain behind to form the vascular tissues of the stem, other cells are thrown off in layers to become leaves. The nuclei in the lower stem-forming cells are distinctly visible in this photograph, which is by Mr. J. J. W[illegible].

HERBERT SPENCER'S GOSPEL

How Mind and Body are Being Perfected Through Infinite Time by Unfoldings from Within

CAN WE NOT SAY THE ENERGY IS DIVINE?

NEGLECTED and ridiculed, Lamarck passed away twenty years after his great work was given to the world. Thirty more were to elapse before the publication of the "Origin of Species" in 1859, exactly half a century after the "Philosophic Zoologique." In that interval men were continuing to feel for some theory of evolution, and two obscure authors independently advanced what was essentially the theory of natural selection. Cuvier died believing in the fixity of species, and Sir Charles Lyell published his epoch-making book on the "Principles of Geology," in which he established the evolutionary idea so far as the earth's crust was concerned, but not until many years later, under the influence of Darwin, did he discard his belief in the fixity of species, and their "special creation."

Meanwhile there was thinking and writing a young engineer whose name is one of the most illustrious in the history of knowledge, and whose fame is steadily increasing as the years justify him. This was the unique figure of Herbert Spencer, the philosopher of universal evolution, whose championship of cosmic evolution, when it was discredited by the astronomers of the day, has already been referred to in another section of this work. Spencer was an evolutionist by instinct, we may almost say; and his discovery of his own discovery was made when he had occasion to read over for republication a number of essays, on all manner of subjects, which he had contributed to the reviews when he began to write. The idea of evolution was implied in all of them.

Spencer was, from first to last, interested above all in man, his conduct and nature and destiny and duty. He did not come to biology by the ordinary route. He went to no university, and never passed an examination. But he was intensely interested in political principles, and there he began. What was progress, and how did it happen? On this subject he wrote and pondered, recognising already certain principles which are involved in organic evolution. Further thought made it clear that there is no law of progress in Nature, in the sense of an irresistible, constant, continuous upward tendency in things. There is, in the living world, an orderly process of change, including change of species, which may result in what we call progress, or in what we call degeneration or retrogression. It is part of the general process of the universe, to which Spencer gave the name of evolution.

It was man, as we have said, who was Spencer's chief concern, and it was through the study of the mind of man that he went on to organic evolution in general. The question is vital to the whole theory of evolution. Our whole idea of the universe is radically different according to whether we look upon the mind of man as a new and special creation, or as historically related to the mental manifestations of the lower animals. In his first great work, the "Principles of Psychology," Spencer set himself to answer this question; and, though the mind of man is not the business of the present section, yet the minds of men and of the lower animals are manifestations of life, so that the problem of the evolution of mind must be considered here. The greater will be the profit if, at any later stage, in this or any other work, we are to study the mind of man himself; for only through evolution can that mind be adequately understood.

Spencer saw that the intellect of man has been formed "by and for converse with phenomena," to use his own words. In declaring this same truth as a cardinal part of his own teaching to-day, Bergson scarcely does justice to Spencer, who proclaimed it

nearly sixty years ago. Spencer saw that the intellect is a natural product, an adaptation, to enable man to deal with the world and its phenomena. It has been shaped *by* converse with them and is meant *for* converse with them. This gives the intellect its effectiveness when dealing with practical things, as Bergson points out to-day, and it explains why the intellect finds itself in the presence of the Unknowable when it strives to pierce below phenomena, as Spencer pointed out long ago.

The Great Thinker who Began to Trace the History of the Human Mind

But if the intellect is a natural evolutionary product, its history must be traced; the evolution of mind is seen to be part of the problem of the evolution of life. We must have an evolutionary or genetic psychology. And of this, which guides the modern study of the mind at every step to-day, Herbert Spencer was the founder. Until his time, every psychologist and philosopher, without exception, had treated mind as he knew it—his own mind—as a thing without antecedents, called into being and indelibly minted by the hand of the Creator. We may perhaps think that this was only natural, since the theory of special creation was generally accepted. Yet it remains almost incredible that it should never have occurred to any thinker that it might be worth while to compare one mind with another. Even if we appreciate the influence of the belief that no animal possessed what could be regarded as a mind, even if we try to appreciate the point of view of the philosophers who regarded savages as degenerate beings, and the savage mind as merely a disfigured specimen of the human mind as it was originally created, it remains inexplicable that practically no one before Herbert Spencer should have thought it worth his while to study the mind of the child. He was the first man to realise effectively that mind has a history.

Spencer's Theory that the Mind has Grown by Traceable Stages to What it is

All the psychologists before him took the adult mind of their own species and race, called it simply Mind, and argued therefrom. This was essentially, of course, the method of looking within, or introspection, which was supposed to be characteristic of psychology, and which is doubtless necessary to it. But Spencer saw that psychology must also be an objective science, studying specimens and varieties and types of mind, just as the geologist studies fossils, the astronomer stars, or the entomologist beetles. This it is which gives Spencer a unique position in psychology. He made contributions to the study of evolution in all its branches, but in psychology he was not only a pioneer by reason of one great idea, but was also a specialist—a master alike of principles and details.

The evolutionary psychology teaches that the mind of the adult civilised man, the mind of the savage, and the child, and the minds of animals are related evolutionally, and must be studied together if any of them is to be understood. Doubtless many savages are degraded, and do not represent earlier stages of the civilised mind, but other so-called savages do represent such stages, as do the child and the animal. We are invited, therefore, to believe that the fully developed and adult mind, even of such creatures as ourselves, is a product of universal and organic evolution, in parallel with our bodies, of which we are willing to admit so much.

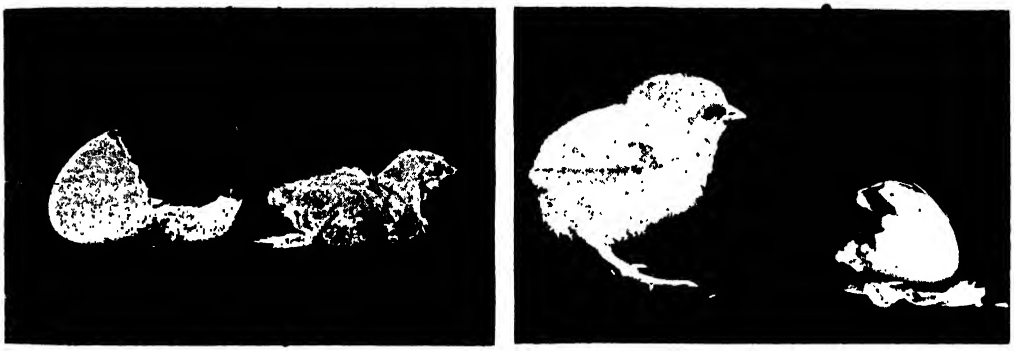
The Growth of Our Own Mind an Illustration of the Growth of the Mind of the Race

Let us consider the history of the individual mind, and it will prepare us for the Spencerian assertion as regards the race. We might take the mind of a dog or an ape for the purpose, but we may as well consider our own case. In considering the history of the individual mind we are forced back, by logic which none can now dispute, to the moment at which the germ-cells derived from the two parents fuse within the body of the mother. At that moment the new individual begins, and already exists as an individual. We all agree that the mind of the adult develops from the mind of the child, nor can we deny that it must develop from the mind of the new-born baby. But science will not let us stop there. We cannot accept the doctrine of the Jesuits, that the human soul is implanted in each human being at the moment of birth. We have no choice but to admit that the mind of the adult is developed from mental possibilities and potentialities found not merely in the child, nor the infant, nor the unborn babe, but in the single cell which is the first stage of the new individual. It is hard to believe. But is not the development of the adult body from this single cell hard to believe? And yet that undoubtedly happens. Furthermore, it must be remembered that the new cell which is to give rise to a new individual, and in which are contained the potentialities of that individual's mind, is itself the product of two other cells, each

of which was as certainly alive as it is, and each of which is the living bearer of the mental characteristics which everyone sees and admits to be transmitted from parent to child. Thus, to reflect upon the history of the individual mind in any adequate measure is to encounter indisputable facts at least as amazing as—indeed, by the rapidity of the development, much more amazing than—the long-disputed facts of the evolution of the racial mind. In other words, the evolutionary assertion as to the history of the mind of man is no whit more incredible than the known facts as to the history of the individual minds of individual men.

Thus prepared by contemplation of the daily marvel which is familiar to every parent, the evolution of the individual mind, we need not fear to lose the doctrine that the human mind is a special creation, lest we should have to believe the incredible processes in the animal organism. By degrees the action becomes localised in a few pigment-cells, more sensitive to light than the surrounding tissue. The eye is here incipient. At first it is merely capable of revealing differences of light and shade produced by bodies close at hand. Followed as the interception of the light is in almost all cases by the contact of the closely adjacent opaque body, sight in this condition becomes a kind of 'anticipatory touch.' The adjustment continues; a slight bulging out of the epidermis over the pigment granules supervenes. A lens is incipient, and, through the operation of infinite adjustments, at length reaches the perfection that it displays in the hawk and eagle. So of the other senses: they are special differentiations of a tissue which was originally vaguely sensitive all over."

Let us not suppose that such a statement explains *how* life makes its adjustments,



THE WONDER AND SUDDENNESS OF BRAIN ACTIVITY THAT COMES TO THE NEW-BORN CHICK
These photographs, by Mr. Oliver Pike, were taken within an hour or two of each other.

We may take the case of vision, the most important, and perhaps almost the most ancient, of the senses. Sensation is, of course, as much psychical as physical; and in this instance the evolution of the sense called vision is clearly parallel with that of the physical structure we call the eye. Here is Tyndall's account, from his celebrated Belfast address, of the Spencerian theory of the evolution of vision:

" In the lowest organisms we have a kind of tactual sense diffused over the entire body; then, through impressions from without and their corresponding adjustments, special portions of the surface become more responsive to stimuli than others. The senses are nascent, the basis of all of them being that simple tactual sense which the sage Democritus recognised 2300 years ago as their common progenitor. The action of light, in the first instance, appears to be a mere disturbance of the chemical

which, as Bergson points out, are not repetitions of the environment, but replies to it. Nevertheless, the passage shows how the evolutionary principle may be applied in the realm of the senses and of the mind. Spencer has more to say about the sense of touch, as primitive. He points out that the parrot is the most intelligent of birds, and its tactual power is also greatest. From this sense it gets knowledge unattainable by birds which cannot employ their feet as hands. Similarly, the extraordinary opportunities of touch afforded to the elephant by its trunk are the basis of its sagacity. Lastly, in the anthropoid apes and in man there is great development of touch, which brings knowledge and feeds and trains the intelligence. These are the kinds of argument which the modern psychologist has in mind when he argues for a great extension of manual training in the education of children. On their purely scientific side they

contribute to a genuine psychology, which traces the origin of the mind, both in the development of the individual and in the evolution of the race.

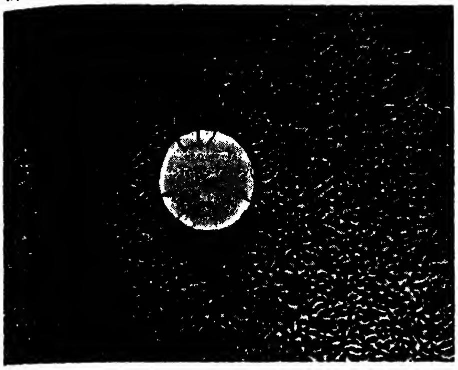
In the attempt to explain the racial development of mind, Spencer invoked, as seems most reasonable, the principles of Lamarck. He observes the extraordinary skill of the chick, which, ten seconds after coming out of the egg, can balance itself, run about and pick up food. How did the chick learn this very complex co-ordination of eye, muscles, and beak? It has not been individually taught, its personal experience is *nil*, but, according to Spencer, it has the benefit of ancestral experience. According to Spencer, the age-long experience of the race is registered in the structure of the young individual—which is, of course, Lamarckism. Thus he argues, in a celebrated passage, that the human brain is the "organised register of infinitely numerous experiences received during the evolution of life, or, rather, during the evolution of that series of organisms through which the human organism has been reached. The effects of the most uniform and frequent of these experiences have been successively bequeathed, principal and interest, and have slowly mounted to the high intelligence which lies latent in the brain of the infant. Thus it happens that the European inherits from twenty to thirty cubic inches more of brain than the Papuan. Thus it happens that faculties, as of music, which scarcely exist in some inferior races, become congenital in superior ones. Thus it happens that out of savages unable to count up to the number of their fingers, and speaking a language containing only nouns and verbs, arise at length our Newtons and Shakespeares."

THE STRUCTURALLY PRIMITIVE EYES OF THE SNAIL THAT HAVE EVOLVED TO SUCH PERFECTION IN THE VERTEBRATES

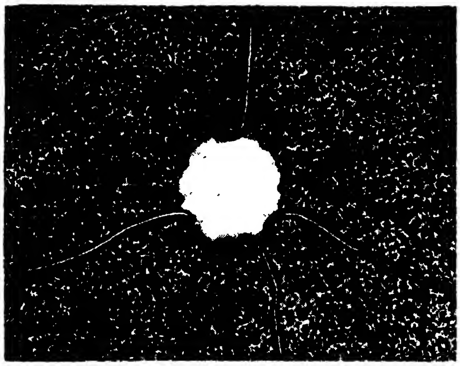
As we have seen already, modern biology finds itself bound to reject this theory of inheritance, and that refusal is, of course, a very serious matter for the psychology of Spencer. We may believe, indeed we must, that mind is an evolutionary product, as he taught; we may believe that the working of an instinct is a complex reflex action, and has been evolved out of the simple reflex responses to light and pressure, and so forth, which we find in the humblest forms of life. But though we learn from him in these respects, and accept the idea that our study of mind must be comparative, like our study of body, since both are evolutionary products, yet we are compelled to reject his explanation of the origin of instincts in ancestral habits, which have gradually become accumulated and ingrained in the very tissue of the offspring. The evidence against this view, and against any such inheritance in the realm of mind, is now overwhelming. It is necessary, also, to add that we have no other explanation which satisfies the mind to offer in place of Spencer's.

Spencer's definition of life is almost the best yet framed. In his view, "life is the continuous adjustment of internal to external relations." This idea of adjustment or adaptation is a cardinal one; and, all through evolutionary speculation and study, that is the great fact which we seek to explain. Spencer's definition does not profess, in itself, to offer any explanation, but it has the great merit of fixing on an essential fact of life, its continuous internal adjustment in reply to the changes and the demands of external circumstances. This adjustment, which proceeds alike in the realm of the living body and in the realm of mind, is a *positive* act on the part of life; it is indeed the essential act of life. Adaptation is its result, alike in the individual and in the race. The biologists who wish to explain everything by the mechanical Darwinian theory of natural selection, and who call themselves Neo-Darwinians, reject Lamarck's explanation of adaptation, both in the individual and in the race, and seek to explain the "continuous adjustment" of

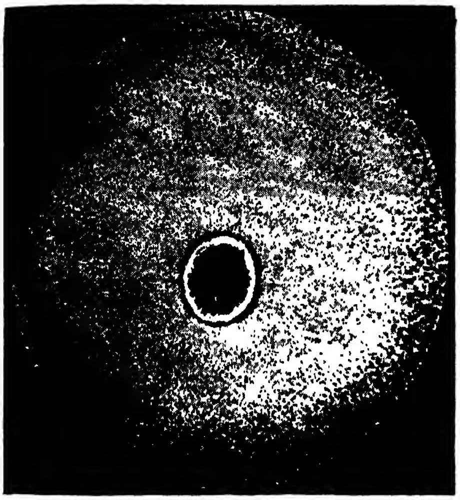
STORIES OF ADAPTATION READ IN EYES



THE EYE-GROUND OF THE AFRICAN ELEPHANT



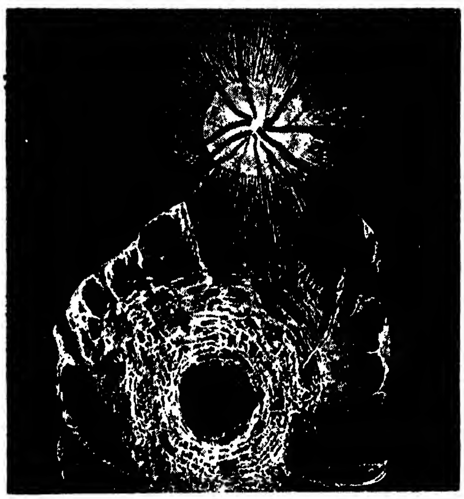
THE EYE-GROUND OF THE AFRICAN LION



THE EYE-GROUND OF THE MISSISSIPPI ALLIGATOR

THE EYE-GROUND OF THE KIWI

THE EYE-GROUND OF THE TIGRINE FROG



THE EYE-GROUND OF THE CHIMPANZEE

Sight, evolved from touch, has become perfected in the eye with ever-increasing complexity. Here are reproductions, from drawings by Mr. Arthur W. Head, of the back inner wall of the eyes of six animals. They include the elaborate eye of the chimpanzee, fully supplied with blood-vessels, and showing, on the right, the part where vision is concentrated; the well-developed eye of the African lion; the eye of a frog, with blood-vessels clearly visible; the protected eye of the Australian bird the kiwi; and, much simpler, and evidently of an earlier type, the inner eye-walls of the African elephant and the Mississippi alligator. The series tell a story in evolution.

life to its circumstances by the theory that what is not adequately adjusted or adapted is wiped out by natural selection. This makes the negative process of rejecting the unadapted explain the positive fact of adaptation. On this grave fallacy let Bergson pronounce:

"That adaptation to environment is the necessary condition of evolution we do not question for a moment. It is quite evident that a species would disappear should it fail to bend to the conditions of existence that are imposed on it. But it is one thing to recognise that outer circumstances are forces evolution must reckon with, and another to claim that they are the directing forces of evolution. This latter theory is that of mechanism. It excludes absolutely the hypothesis of an original impetus, I mean an internal push that has carried life, by more and more complex forms, to higher and higher destinies. Yet this impetus is evident; and a mere glance at fossil species shows us that life need not have evolved at all, or might have evolved only in very restricted limits, if it had chosen the alternative, much more convenient to itself, of becoming rigidly fixed in its primitive forms."

A GORSE SEEDLING WITH THE TREFOIL LEAVES OF ITS REMOTE ANCESTORS

Plainly, therefore, the evolution of life, and the "continuous adjustment" and adaptation of those forms which have survived, cannot be explained by pointing out that forms which were not adapted would become extinct; and if we are to find the source of the push or force which drives life on and is witnessed in its unceasing adaptations, we must go behind it to discover, in Spencer's words, "the infinite and eternal energy from which all things proceed."

Spencer's definition of life, which guides us in our interpretations at every stage, is contained in his great work on biology, which he found himself compelled to deal with in the interests of his philosophy of man and man's mind. The special value of this masterpiece to-day is that it is an exposition of organic evolution which is independent of the truth of any particular explanation or series of explanations of its factors. In 1894, when the late Lord Salisbury delivered his presidential address to the British Association, in which he criticised the idea of natural selection, Huxley took the opportunity, when seconding the vote of thanks, to say that "if all the conceptions promulgated in the 'Origin of Species' which are peculiarly Darwinian were swept away, the theory of the evolution of animals and plants would not be in the slightest degree shaken." A more recent historian observes that though the principles of evolution, as systematised by Spencer, received recognition only through the influence of the special doctrine of natural selection, they may yet survive that doctrine. Natural selection, or, in Spencer's own phrase, gladly adopted by Darwin, the "survival of the fittest," is invaluable in teaching us that survival is not at random, but depends upon superior fitness, but it tells us nothing as to the origin of the fittest; and that is why, to-day, such work as Spencer's is coming to be seen at its full value, for it goes deeper, and builds the positive facts of evolution upon the very nature of life.

The commonest accusation brought against evolutionists is that they are materialists. Spencer's definition of life may be quoted in evidence—by those who have read no further. Life is indeed manifested to us as the "continuous adjustment of internal to external relations," but the how and the why of the adjustment remain unanswered, since, as Bergson points out, life does not repeat the shape of its surroundings, but replies to them; and since, also, life is never content with adequate adaptation, but keeps on pushing towards other forms, of which some will be higher than any that have gone before. Let those, then, who would suppose Spencer's definition to be merely mechanical, and inadequate to express the mystery of life, be reminded of his own comments upon it. He fully realised that, in the last resort, the nature of life is incomprehensible: "It needs but to observe how simple forms of existence are in their ultimate nature incomprehensible, to see that this most complex form of existence is, in a sense, doubly incomprehensible . . . only the

manifestations of life come within the range of our intelligence, while that which is manifested lies beyond it." This supposed materialist, speaking of life, says that its "phenomena are accessible to thought, but the implied noumenon [the reality of which phenomena or appearances are only the manifestations] is inaccessible." Once again we nail to the counter the libel, still propagated by academic philosophers, that Spencer was a materialist.

Elsewhere reference has been made to one of Spencer's notable contributions to what may be called the mechanics of evolution. We have seen that all evolution has depended upon cell-division, for cell-division means the possibility of cell-variation, which underlies all evolution. The differences in cells, as they divide, involve different function and division of labour, so as to produce an organised body such as ours; and if the new cells, instead of adhering, pass on to form new individuals, some of those may give rise to unprecedented forms of life. Hence the importance of Spencer's "law of limit of growth," which finds the key to cell-division and to the observed limit of size of individual cells throughout the living world in the fact that an enlarging cell increases its volume at a greater rate than its surface, by which it feeds and breathes, and must therefore divide, if the "push" of life is to be maintained.

A YOUNG GORSE PLANT THAT HAS DEVELOPED PROTECTIVE PRICKLES WHEREBY IT IS ABLE TO THRIVE ON OPEN HEATHS

Spencer accepted Lamarck's view of the inheritance of the effects of use and disuse, and in that one respect we now reject his contributions to the study of heredity. But in another respect we have confirmed him. For convenience' sake we call the cell the "unit of life," in order to emphasise the truth that the bodies of all living creatures are made up of cells. But we have already seen that, for a time at any rate, the divided portion of a cell will live. The real unit of life must therefore be something smaller than the cell. This we see clearly if we consider, above all, the case of a germ-cell, the bearer of the hereditary characters from parent to offspring. This cell is a unit in a true sense, but it is made up of smaller units, which are themselves alive. This idea will be all the more reasonable to those readers who have remembered our argument, in the discussion on the origin of life, that the cell is a comparatively late stage in the evolution of life, and that there must have been many simpler forms of life before that triumph of organisation, as it really is, which we call the cell. The cell is really the *anatomical unit*, the unit of structure. It is, of course, made up of vast numbers of chemical molecules, simple and complicated, which we may call chemical units. These molecules are not themselves alive. But intermediate between the cell and the molecules there must be units which are composed of many molecules, and which are *alive*. These discharge the functions of life, and to them Spencer gave the name of *physiological units*—a "magnificent all-sided conception," in the words of one of his most discerning critics, Grant Allen.

Since Spencer's day every biologist who has studied the cell has seen that he was right, and that there must be invisible living units in the cell, smaller than it is, but larger than mere chemical molecules. Weismann, Haeckel, and many other biologists have introduced new names for the idea, but one and all are simply renaming what Spencer called physiological units. If we recall the facts of cell-division we shall see that the modern microscope goes a little way towards actually seeing what Spencer saw must exist. The division of the nuclear chromatin yields a series of individual bodies which we called chromosomes or colour-bodies, and these, as we saw, split and yield halves which go to each of the

daughter-nuclei. Each of these chromosomes is obviously a living unit, smaller than the cell. But even chromosomes may be seen to be composed, in some cases, of smaller units, and these are doubtless composed of still smaller ones, which, invisible by the most powerful microscope, are the real units of living substance.

The Infinite Divisibility and Complexity of the Smallest Germ-Cell

There is basis in this great idea of Spencer's for forming some kind of visual picture both of heredity and of development. The number of physiological units in, say, a germ-cell, or in the new cell formed by the union of two germ-cells, may be thousands; and if we endow them with variety of form and function, such as they must have, we begin to see the possibility of the transmission of numerous characters from parent to offspring, and the appearance of those characters in the course of the development of the offspring. When we think how tiny these germ-cells are, and yet how they somehow contain the physical basis of all those details of structure which we see in the fully developed individual, the problem before us at first seems hopeless of comprehension. Most of all is it so if we think of the cell as a simple thing, the "unit of life." It is unthinkably complex, crowded with smaller "physiological units," the possible number of which can only be realised if we appeal to the physicists and ask them to tell us about the size of atoms and molecules. Their answer is a staggering one, though the readers of another section of this work should not be unprepared for it. "The physicists report that the image of a *Great Eastern* filled with framework as intricate as that of the daintiest watch does not exaggerate the possibilities of molecular complexity in a spermatozoon (a male germ-cell), whose actual size may be less than the smallest dot on the watch's face."

The Nervous System and Seat of Intelligence Developed from Contact with the Outer World

Plainly, therefore, there was nothing unreasonable in the suggestion that the physiological units in a germ-cell might number thousands, and the facts of heredity and development begin to become more intelligible. Lastly, on this point, it may be noted that the Mendelian study of heredity entirely confirms the theory of Spencer. Mendelism clearly points to the existence, within germ-cells, of numerous *somethings* which determine the future development of the individual. These things go sometimes into one germ-cell and sometimes into another, being distributed in an orderly way among the germ-cells in the process of their formation. They are called "Mendelian factors," and we see that the physical basis of these factors must correspond to those functional units of the living cell which Spencer was the first to recognise.

To one other fact of development does Spencer contribute. We saw his argument that touch is the mother-sense, and that the others are evolved from it. Thus the nervous system, which is the centre of sensation, should be derivable, historically, from the *outside* of the body, next the external world. Yet we find the central nervous system in the inside of the body —inside, indeed, a complete case of bone, which, in its turn, is covered with muscles and skin. But if we trace the history of the individual we find an astonishing fact that the entire nervous system, brain and spinal cord and all, is developed from the outermost layer of the embryo, and thus has the same origin as the skin. At a very early stage, a portion of the outer layer is turned inwards, becomes enclosed in the substance of the developing organism, and ultimately develops into the nervous system, the seat of intelligence. This adds force to the view that the intelligence was evolved by and for converse with the outer world, if we infer, from the history of the individual, that such has also been the history of the nervous system in the evolution of life.

What Science Says Explaining the Fall of the Birth-Rate with the Rise of Civilisation

Yet another contribution of the apostle of evolution to our understanding of its processes must be mentioned, especially as it bears upon the problems discussed in other sections of this work. Spencer built the whole of his philosophy of evolution upon the doctrine of the conservation of energy, which he recognised to be as true of the energy displayed in living organisms as anywhere else. If, therefore, energy be expended exclusively upon the development of the individual, there will be none left for the purpose of reproduction. On the contrary, if the individual, directly it reaches maturity, spends all its energy upon reproduction, its individual life must be sacrificed. This, indeed, we see in the case of those organisms which subdivide for reproduction so that their individuality totally disappears.

From such considerations Herbert Spencer was led to frame a "law of multiplication," expressing what he called the "antagonism between individuation and genesis." This

antagonism was asserted by Spencer to be true of the whole of the living world, as, indeed, it must be if the law of the conservation of energy be valid, for one cannot eat one's cake and have it. But from this law it follows that, if the quality of individuals rises, if their maintenance and their development to maturity require much energy, expended for long periods, so much the less will be the quantity of energy which they have available for the purposes of reproduction or genesis. They must therefore produce fewer offspring, and thus offer the remarkable paradox, which to-day puzzles and outrages so many commentators, that, as life ascends and becomes more successful, the birth-rate falls. It has been falling since the dawn of life, on the whole just in proportion as life has ascended, simply because the superior development of individuals has ever involved the reduction in the number that life could afford to produce, unless it was to go bankrupt.

The Problem of Non-Multiplication by the Most Highly Developed

That this law, discovered by Spencer, is philosophically and practically true cannot be questioned. It is one of the cardinal facts of evolution, and can never be omitted from any attempt to explain the factors of evolution, such as we are all trying to make to-day. Spencer clearly shows that this law of the falling birth-rate, from the humblest to the highest forms of life, is beneficent and economical, for it reduces the proportion of death and birth to life, and it coincides with a steady reduction in the mortality of the immature, which seems and often is wasteful, though much less so than is often supposed, as we have shown elsewhere. This doctrine applies to man and woman as it does elsewhere, and most notable consequences may be deduced from it regarding the individual development of women, so long as "genesis" involves a vastly greater strain upon the female than upon the male organism. For it would appear that the highest and most exhausting development of the individual, without leaving any energy to spare for other purposes, may tend to produce, as the recent American evidence of the higher education of women suggests, a being who is admirable and complete in herself, but who fails to perpetuate her kind for the coming world. It will suffice thus to hint that the fundamental law of all life, enunciated by Spencer half a century ago, may have to be reckoned with by sociologists and eugenists for their own purposes no less than by the evolutionist for his.

Lastly, let us observe what evolution really means, according to Spencer, as contrasted with any process of manufacture. Evolution means internal development of dissimilar, definite products from something which is all similar and indefinite. Contrast, for instance, the solar system and the shadowy nebula or fire-mist from which it has evolved. Contrast the body of an adult organism with the undifferentiated, though marvellously potential, cell from which it has been evolved. Contrast a modern society with a primitive horde of human beings. Evolution is always, as the name implies, a process of unfolding from within.

Growth from Within Through the Operation of a Creative and Eternal Energy

Thus we contrast manufacture with evolution. If we wished to make a new society in some uninhabited country, we should have to import a certain number of traders and doctors, and factories and churches, and customs, and so, by putting together a sufficient number of the right things, we should make a society. So, when we manufacture a machine, we construct wheels and axles, and gear-boxes and levers and cranks, and what not. The machine is manufactured by putting all these together, by "assembling" its parts, as the engineers say.

But living art, living beings, the living universe, are not so manufactured by putting parts together. They grow from the mind of the artist, from the power of life, from the creative and eternal energy of Deity. Bergson sees all this to-day, and states it as follows, the italics being his: "Mechanism holds that Nature has worked like a human being by bringing parts together, while a mere glance at the development of an embryo shows that life goes to work in a very different way. *Life does not proceed by the association and addition of elements, but by dissociation and division.*"

Can we not Say that Creative and Eternal Energy is Divine?

That is why the future of life always overflows its present, and beggars our predictions. Evolution is a growth from within, an unfolding of potentialities which are inexhaustible, and to which we, ourselves but illustrations thereof, can put no limit. Such is the idea of organic evolution, as part of universal evolution, which we owe in its modern form to the great Englishman who thought that God must transcend our ideas of consciousness and will as these transcend mere mechanical motion, but who has not yet been judged worthy of a tablet in Westminster Abbey.

NATURE'S RESTING-HOUR IN AUTUMN

These pictures give us the feeling of autumn's refreshing pause, when the earth is quietly collecting her life-producing energies in anticipation of a fresh outburst under the returning sun.

AUTUMN'S STORAGE OF LIFE

Mistakes Made About the Season when Nature Cheerfully Consolidates Her Reserves of Strength

THE SECOND SPRINGTIME OF THE YEAR

ALMOST all people regard autumn as a time of decay, if not of melancholy. They see the leaves losing the fresh green colour which is as much the sign of health in plants as a pink complexion in man. As this green, or chlorophyll, disappears, shades of yellow and red and black take its place, until, as it seems, the leaves are too weak and lifeless to hold any longer on to the twigs. They fall, and the trees become, as Shakespeare wrote, "Bare ruined choirs where late the sweet birds sang."

In autumn the days grow shorter, the mists cover the low places in the mornings, many of the birds have ceased to sing, and many more are flying away to other countries. Surely autumn is a time when the world about us is losing its vitality.

In some countries this is so. It is so in the North. Even, for example, in Newfoundland, which has a beautiful climate in autumn—as good as the English—the birds disappear, and none arrive, and the farmers begin to cease work in the fields. In Canada less corn is sown in the autumn. If seeds are sown then, the majority of them would be killed by the weather of the following months, or, rather, seeds that lay dormant and did not sprout would perish, and those that grew would produce plants that would have little chance of living through the cold winter.

But in England, which in many ways is a model of temperate climate, seeds sown in the autumn germinate well and quickly, and produce, on the whole, better plants than the grain sown in the spring. Winter oats—oats sown before the spring comes—as a rule yield a larger crop and resist disease and drought very much better than grain sown in the spring. Many florists prefer to sow such annual plants as sweet peas in the autumn rather than in the spring, though the difference between the two is not very highly marked. The reason is that the plants have made good roots before the excessively bad weather comes; and by springtime, though they have not grown a great height, they are ready to share at once in the new warmth and the longer hours of light, and they are "hardened off," as gardeners say. The various diseases do not find them such susceptible victims.

The truth about most autumn and spring sown grain is that, in a great majority of cases, the autumn sown is much the best. But if spring and early summer are all that they should be in respect of continued heat and moisture, the difference is not great; and if the autumn happens to be very wet, or the winter exceptionally hard, the spring crops do the better.

But, apart from the comparison of the two from the point of view of the farmer, it is clear that autumn is in many ways a sort of spring. Like spring, it is also a seedtime. Of course, almost all the common plants, notably the annual weeds, such as dandelion, or hawkweed, or shepherd's purse, sow themselves of necessity in autumn. Some of these seeds come up at once, some lie dormant. Many farmers, as winter approaches, like to see a quantity of little seedlings sprouting up over the fields.

In favourable years one may see fields as thickly covered with small seed-leaves as if they had been sowed on purpose. They can easily be destroyed; indeed, very many will be killed by the weather, and, when killed, they will do no little good to the land. They will restore to the earth the fertile stuff that it most requires—the nitrogen without which few plants can flourish.

In looking, then, at the "happy autumn fields"—many of them green with the

waving blades of oats and wheat, among which are great flocks of larks that have just arrived in England—we have to think of the season as a time of growth and vigour. But it is not only in the seeds and on the fields that this vigour is apparent. It is hardly less apparent to the eye of the scientific observer, in the trees and upon some of those plants which have seemed especially to express, with their withered leaves the period of decay.

It is not quite true to say that the leaves decay and fall. Sometimes, no doubt, when a hard frost comes before its time, the leaves of some trees, especially the ash-trees and chestnuts, are shrivelled up and killed and so fall prematurely before their time. But generally, and in regard to most trees, this is not so. The facts are that, in the first place, the tree throws off the leaves with a vital and vigorous action which it is most interesting to watch and observe closely; and, secondly, that the leaf which seems to be simply withering away for want of vitality is also engaged in a busy work which may be compared with that of the squirrel who is storing nuts in his winter nest high up in the tree or in a hole in the ground at its foot.

SHOOTS OF HORSE-CHESTNUT IN AUTUMN, SHOWING HORSESHOE MARKINGS AND STICKY CEMENT

What is the green in the leaf, and what purpose did the leaf serve in growing and becoming green? The leaf is a part of the machinery of the tree, and, after the roots, much the most important part of the machinery. It is designed to help in adding vigour to the whole. Throughout the whole of the spring and the summer it was engaged in manufacturing life-blood for the use of the tree. But it has a further task. In autumn it is engaged in passing the stores that it has manufactured into the reservoirs. The chlorophyll—or green-stuff, or life-blood—is quite literally poured back from the leaf into the tree. With the help of a microscope, and by careful inspections of the build and structure of the leaf and twig, we can see the pipes, as it were, along which the fluid is sent. What we cannot see, what no eye has ever yet seen, is the force which does the work, and prompts the leaf in this particular case to send the stuff of life back into the tree. But, though we do not know the original force, we know the fact. We know the stuff goes back, and this ebbing or flowing back of the tide of life is a work not of decay, but of vigour. It needs and calls forth energy. Outwardly, most of us will not notice the result of this energy till next spring, till the tree, fed with this new supply of energy, begins to put forth again more leaves that are to make yet further supplies.

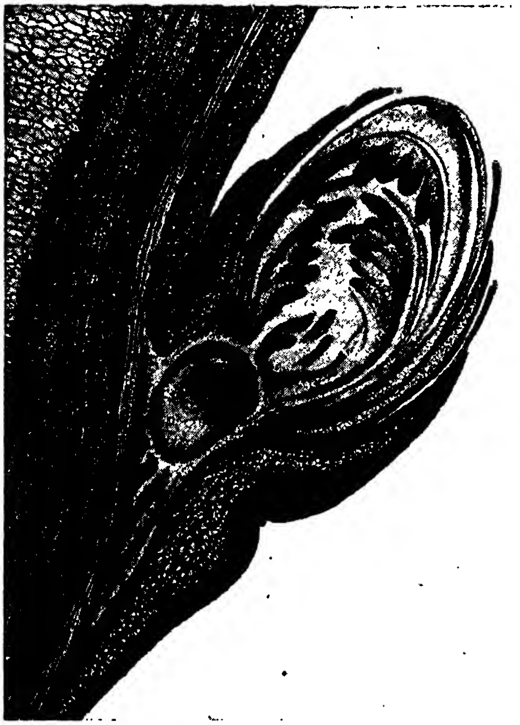
But, without using a microscope, anyone can see growth going on up till quite a late period in the year. In the axil, or angle near by the leaf with the twig, the next year's bud has been nestling, perhaps two or even three buds, one inside the other. These buds go on forming and swelling during a considerable part of the year; and they are fed to some extent by the chlorophyll passed back by the so-called dying leaf. There is no time of the year when we can say definitely that these buds are formed. Some are leaf-buds, some are fruit-buds. A skilled fruit-grower can tell us very early in their life which buds on his trees will bear flowers and which will bear leaves, the flower-buds being fatter and stouter and less pointed than the leaf-buds. But now we are speaking of leaf-buds. Whenever the bud takes its true form, it is certain that autumn is a very important season; and it is popularly believed among fruit-growers that the show of blossom in the coming year depends most on the weather of the preceding autumn.

It is an interesting study to watch these buds and reserve buds, to see when they appear, and swell, and cease to swell. Not the least interesting part of them is the way they are cased in, and hermetically sealed against the attacks of insects or weather. The buds are particularly interesting on the ash, bearing a certain resemblance to a deer's foot. They become at one period pitch-black, and no tree has a greater tendency to grow a succession of reserve buds. But they are perhaps easiest to observe on the horse-chestnut, which, in a variety of ways, is a delightful student's tree. The buds are very big and conspicuous. With a sharp knife we can so cut the bud as to see all the parts of the coming flower-spray months before its time for opening to the world. It is also conspicuous for the sticky cement with which it closes the bud against any possible attack.

If we examine any chestnut twig—and the marks are especially noticeable in autumn—we shall see at various distances along it successive patterns which resemble a little a horseshoe very much opened. There is a rough crescent of smooth bark, and upon it a line of slightly raised lumps suggestive of small nail-heads. The marks are so curious and evident that they have been noted and used by scouts, who have written their own signs on the twigs; and the writing has entirely escaped notice because of the number of natural marks found on each side of it, and on neighbouring twigs.

This mark on the chestnut is a sign, blazoned on the bark, attesting another of the vigorous actions of the autumn season, which the world calls a season of decay. The horseshoe is the mark left by the fallen leaf, but it did not fall by its own want of vigour so much as by the active effort of the tree to get rid of it. In nearly all trees, when the leaf has finished its work, there grows, between the leaf and the twig from which it sprang, little layers of cork or corky substance. In the different varieties of trees these little corky lumps take different patterns; and an expert forester could tell us the name and variety of most trees in mid-winter solely from these patterns.

In any course of Nature study, or in the natural course of observation, a collection should be made of these various markings, all of which fall into patterns as simple and as distinct as are the shapes of crystals in different forms. As each form has its distinct crystal, so each variety of tree has its proper leaf-pattern; and the pattern indicates the active effort made by the tree to expel the old leaf.



ENLARGED SECTION OF TINY BUD ABOVE RIGHT-HAND HORSESHOE MARK IN THE OPPOSITE PICTURE

We may easily tell that there is an active effort by noticing the contrast with a dead or half-dead bough. Half break any twig so that it still hangs on the tree but does not any longer share in the flowing of sap and of the life juices. What happens? The leaves wither quickly. They do not go through the slow, natural process, nor do they gradually, or indeed at all, take on the various autumn colours of yellow and red of the neighbouring leaves. Instead, they wither into browns and blacks, and hang where they withered. Their torn and withered shapes will remain on the broken twig long after the other leaves have turned colour and fallen. This means that the dead or dying twig had not enough vital energy left to thrust off the old leaf, as did the living twig which felt the energy of autumn.

Of course, all trees do not behave in the same manner. Oaks will often keep on many of their brown, withered leaves right through the winter, and they will not fall till the new leaves begin to swell in late

spring. Beech-trees also have a tendency to keep their red-brown leaves, and hornbeams, distinguished from beeches by the dull brown of their old leaves, do much the same. So-called evergreens, again, throw off their leaves for the most part in spring, and there is no easily traceable backflow of chlorophyll in autumn. In countries such as Australia, where there are no deciduous trees,—that is, trees which lose all their leaves every year—the vigour of autumn is much less real and very much less perceptible than in England. On the other hand, there is not the same appearance of decay, as the leaves keep their greenness throughout the winter.

Again, annual plants do not behave in this way. Generally speaking, plants are divided into the three classes of annual, biennial, and perennial.

The annual plants, whose roots do not survive after their one season, put their chief vigour into making seed to ensure the growth of new plants in the following year. Many of them will go on wrestling up to late in the year to produce seed if the first efforts fail. Sweet-peas, for example, will flower into October if no seed is allowed to set earlier, and the common weeds will persist in throwing up flower-heads if we prevent the first flowers from coming to seed. It would be of no service to these plants to feed the roots with the riches they have stored.

Corn of all sorts, it will be noticed, ripens upwards, as farmers say ; that is, the straw hardens and loses its greenness and its sappy nature first at the bottom, and finally close to the ear.

Biennials, on the other hand, spend their first year in building up strength in the root in order to flower well in the following year or years, for, though they are called biennials such plants often last more than two years. The garden carrot is a good example of this division. What we eat is the food-supply laid up by the plant for use in the following year. This we steal, and turn to our own use, before it can be turned to its more proper use.

AUTUMN IN THE WOODS, SHOWING THE RICH CARPET OF FERTILISING LEAVES

This photograph and other pictures that illustrate these pages are by Messrs. Hinkins and Son

The chief part played by the leaves is to send stores of food to the bulbous root. In perennials, plants which live on indefinitely from year to year, the vigour of the plant is always lessened if we cut off the leaves before they have parted with their green juices. Almost every gardener knows this truth in respect of his bulbs.

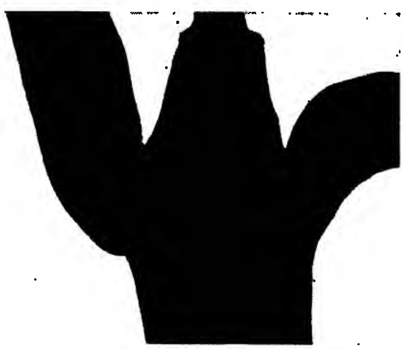
The tops of crocuses, daffodils, and snowdrops, however untidy they may look, are not cut off till they are withered; and the reason of this is that the leaves are feeding the bulbs. Indeed, in many bulbs, notably the crocus, the leaves grow to a great length, after the plant has done flowering, in order to absorb more food for the bulb. As we can increase the vigour of plants by letting the leaves wither and part with their fuel, so we can quite easily destroy plants by cutting off the leaves. Even that persistent thing a plantain can be made to perish by successive cutting of the leaves. Beds of nettles will not survive the frequent use of the scythe. The most ineradicable of all weeds is the convolvulus, or bindweed. Each tiny bit of white root has the power of sprouting and producing great tendrils. But convolvulus is as surely killed as any other green-leaved plant by plucking the leaves before they begin to languish.

Autumn is a season of "mellow fruitfulness" in many ways, some of which are little noticed. We all notice the scattering of seed. The luscious stuff round the seeds of an apple persuades the bird to help the fruitful part to be carried away or made fit for germinating, and the thistledown is wafted by its wings and by the wind many miles away to start another plant. But a more conspicuous example of the energy of autumn is to be seen in such plants as the blackberry, which is on the way to become an evergreen, at least in England. In the autumn months the long shoots bend down till, at the end of the fine curve, they touch the ground. If the soil is at all congenial, or if the top is in any way pulled down into it, the leaf-shoots begin to turn into roots, and when spring comes it will be found that a completely new plant is produced. The blackberry has "layered" itself naturally. This layering has become a much more general garden and horticultural process of recent years since other berries have been "created" by scientific gardeners. There are added a number of plants—the loganberry, the lowberry, the newberry—all descended from the blackberry and the raspberry, which layer themselves easily and well; and farms of them have sprung up in Kent and Worcestershire. They can be multiplied either exactly in Nature's way in autumn by covering the tip of the shoot—which makes the best plant—or by half cutting

EARLY SPRING BY THE LAKE OF GENEVA, SHOWING SOME LEAVES ON A BRANCH THAT HAS LACKED THE ENERGY TO THROW THEM OFF

through the joints and pegging them down. In this way quite a number of plants may be got from one shoot. But, as is generally the case, Nature's favourite way is the best. Many of the climbing roses can be multiplied very easily thus, as also can gooseberries and currants.

Autumn, then, is a sort of spring, a first spring, preparing for spring proper. Seed is sown and seed germinates. Life-blood is conveyed to roots and twigs, and buds form and swell. August is perhaps a more restful time in Nature than late autumn. Of course, the ripening of fruit is a part of the activity of trees, but it has to be remembered that the ripening and maturing of fruit are rather different things. After they have reached a certain pitch, fruit and seed have in themselves the power of maturing. In the ripening—that is, in bringing the fruit to the full size and development — the tree plays a part, but when this stage is reached the fruit, as it were, matures itself. Its consistency changes and it becomes more palatable. This maturing of fruit is, however, not quite the same as the drying of seeds, though it is like it. Wheat is left in the field in sheaves and stooks in order to mature, in one sense of the term, but the maturing is partly connected with the loss of moisture. The less moisture there is in a grain of corn, and the more polished and transparent it looks, the better is its quality. It is said by the millers to be "stronger." However, no English wheats are so strong as those grown more quickly under the hotter suns of Canada or South America.



THE DARK LINES SHOW THE GROWTH THAT FORCES THE LEAF TO FALL

At every season of the year some sort of growth is proceeding. One of the most curious tests of this is the sprouting of bulbs or tubers. By no sort of means can some bulbs be made to grow before their proper season. The bulb has to go through some mysterious process within itself before it is ready. The bulbs have been called by a name first given to coal, "bottled sunlight." In a sense they are: that is to say, the leaves have taken in sunlight, changed it to their use, and transferred it to the bulb, in which it will serve as food for next year's growth. It has always to be remembered in botany that the sun and air, through the leaves, do more for the plant in respect of food than the water and earth, acting through the roots. We may be allowed, then, roughly to call the bulb or tuber—for a potato is like a snowdrop in this respect—"bottled sunlight." But this sunlight in the bulb has to go through some untraceable change, working right through the winter months, before it can be converted into growth, into leaves and flowers. All efforts to force these bulbs unduly have failed, and the only method of getting flowers from them out of date is to freeze the bulbs. When they have come to their full maturity it is easy to stop them sprouting. All that is necessary is to lower the temperature sufficiently, and, obeying the law of self-protection, they will not shoot till warmer and safer conditions are promised.

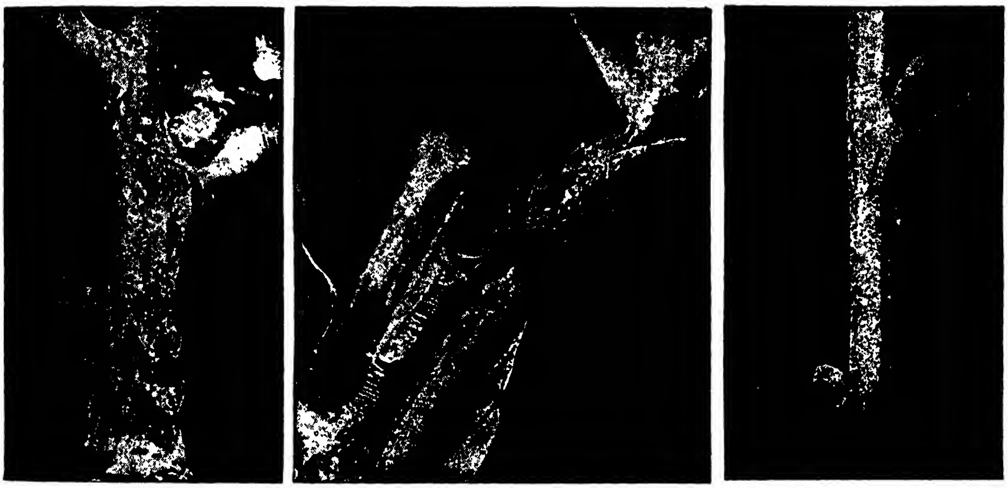
The circle of the year is much less definitely marked into seasons for this thing and that than is generally supposed; and the continuity has a great deal to do with many farming and gardening operations. It may be said that sowing and planting can be done from September, or earlier, to the end of the first week or two in May—that is, during three-quarters of the year; and, of course, in the garden where successive crops are required sowing continues much later than the first half o May. Of course, these things are not done in foul weather; and two periods, an autumn and a spring, mark themselves out, but it is true that there are seven months or so of the sowing and planting season. August is perhaps more like the end of the year than any other. Poultry-keepers, for example, find that it is useless to rear chickens after the end of July, because they cease to grow, whereas chicks hatched in early December grow quickly.

Many birds moult at this time and lose their vigour, whereas they return to first plumage and full vigour a month or so later.

As with animals, so with plants. The fall of the wheat harvest, which never begins before the latter half of July, and is often not completed when September is well advanced, is the sign of the end of the most important stage in the year. After this a new vigour begins to appear again; and, as has been said, the fall of the leaves,

though also due to other causes, is one sign of it. In modern farming it is becoming the custom to plough up the land with the utmost speed; indeed, it is not uncommon to see the ploughs at work in a field before the carts have left it with their load of sheaves, so quickly does the farmer make one operation follow on the heels of another, realising that he cannot too soon open his land to the air, and add manure, and, with the help of the weather, prepare a seed-bed for the grain he is about to sow. Under every tree and bush and hedgerow, and to some extent over the fields, Nature herself spreads a fertilising substance. The leaves, when they fall, have parted with almost all their useful substance except lime. We have already seen, when we discussed the soil, how very necessary lime is to its fertility This maize, which English farmers are now beginning to grow in some counties, are hardly yet ready to cut. When the last leaves are falling from the stems at the end of November, we may find the honeysuckles putting out long leaves, and the catkins are very apparent on the hazels. Quite a number of weeds are in flower through the winter, and there is seldom a year when we cannot find primroses in the woods on or about Christmas Day. Directly the days begin to lengthen, gardeners become busy.

The moral of it all is that the land is capable of bearing successive crops within the year. We may have green crops for the stock from early summer till late autumn, from the first crop of tares till the last of maize. One of the most delightful sights of autumn is to see the clover, which



THE BUDS FOR THE NEXT YEAR'S GROWTH ON THE OAK, THE BEECH, AND THE EDIBLE CHESTNUT

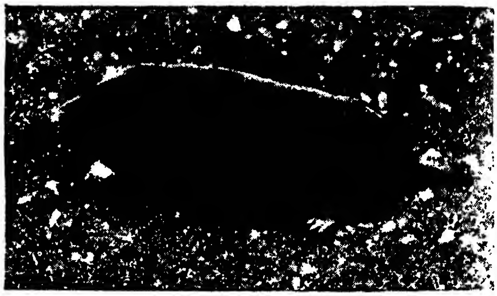
is partly supplied by the leaves when they fall, so that nothing is wasted. What is taken out of the ground is returned with much else that comes from the air and sun.

With the help of glass, man can in some degree defeat the seasons, but he cannot do so altogether. The French, who are intensive gardeners, consider that the year very properly is made to begin on January the first. January is one of their busiest months, and their frames are full of seeds that germinate and grow at an astounding speed before January is out. With this school of gardeners also August is regarded as the end of the season. In almost every part of England we may see on all hands signs of the continuity and overlapping of the seasons. The first green blades of wheat and oats are springing up on the tilths. At the same time green crops, such as was in the ground along with the corn, begin to cover up the hard ridges of the stubble. But more crops than clover can be grown simultaneously to be reaped successively. In Lancashire, for example, on some of the best farms, two successive crops of potatoes are grown on the same field.

Nothing is more kindly than our spring-like autumn, which gives us a double chance of getting a fair harvest. Even those who have just begun to dabble in gardening, growing a few flowers from penny packets, are told that they may either sow their seed, as Nature usually sows it, in autumn for flowers in the next year, or in the spring for flowers in the same year. This, too, is a lesson in the seasons; and the nature of the season is the very first thing to be learnt by all those who have any traffic in the ways of plants.

THE INSIDE AND OUTSIDE OF A MOLE COLONY

GENERAL VIEW OF A MOLE COLONY—A STRIKING PHOTOGRAPH OF A FIELD IN HAMPSHIRE



VIEWS OF THE MOLE ABOVE GROUND, SHOWING ITS STRUCTURAL FITNESS FOR BURROWING

INSIDE A MOLEHILL—SHOWING HOW MOLES EAT THROUGH THE ROOTS OF CROPS

The mole, our best native engineer, helps the farmer by destroying harmful grubs, but himself becomes a nuisance when his mounds, thrown up in all directions, make a field temporarily valueless.

The photographs on these pages are by Messrs. Hinkins and Son, Douglas English, and S. W. Johnson.

THE INSECT-EATERS

One of the Great Groups of Animals which Maintain the Balance of Nature and Preserve the Food of Man

LOWLY BENEFACTORS OF THE WORLD

Dean Buckland, who was among the boldest explorers in the realm of diet, was wont to declare that, after eating his way through nearly the whole animal kingdom, his progress was stayed by the insects. A blue-bottle fly was too much for even his tolerant palate. It is fortunate for the human family that not all mammals are dominated by such prejudices, or there would be no order of Insectivores, and in this case very little other life would exist on land.

For insects, if left unchecked, would speedily denude the earth of all the vegetable growth by which the life of the larger animals is supported. It is the function of the insect-eating animals to help in diminishing this great menace. Of course, there are other agencies working in the same direction. The birds are notable aids to maintaining the balance of Nature; so are countless kinds of ichneumon flies, and many carnivorous insects. But, no matter how numerous and varied are their allies in the war on insects, nothing can take away from the high importance of the insectivores. Inestimable is their value as a scourge of ground-haunting insects which, in perfect form or larval, prey upon crops; and the significance of the tree-climbing insectivore's contribution to the weal of the world is scarcely less evident.

Mighty as man seems, his existence is at the mercy of the insects; and the insect-eating animals are among the most powerful of the bodyguard that maintains law and order for him. It would matter very little to the insectivores if the human family were blotted out. Indeed, it might be to their advantage, unless the removal of one great check upon their multiplication led to excessive increase and attendant disaster such as we see periodically in the life of the lemming. But the case would be very different for man if the insectivores were suddenly exterminated. Science could not invent a substitute quickly enough to avert widespread ruin. Every time that a shrew or a hedgehog crunches the larva of some plant-destroying insect, a work of great advantage to man is performed. The achievement of the individual may seem small, but the aggregate effect is enormous. And these animal allies of ours, who flee from us as from the most terrific of ogres, and yet work almost continuously for our physical salvation, are among the most humble of quadrupeds. With the marsupials and the egg-laying animals, they are the most primitive of mammals.

Life has flowed past them in an ever-widening stream, developing into new forms, waxing great and strong, but leaving them practically unchanged in the structure and habits which they acquired when all the world was comparatively young.

There is in the British Museum a section of a tree that was cut down when Queen Victoria had been over half a century on the throne. That tree, when Charlemagne was crowned Emperor in Rome, a little over eleven centuries ago, had already been in existence as long a period as has the Manchu dynasty, against which the standard of revolt was raised in China in 1911. "A living fossil," people say, when they look upon one of the fellows of this sequoia tree which are still growing. But in a very much smaller botanical specimen, the maiden-hair tree, that is to be seen at Kew and in other private collections, we may note a "living fossil" of another kind, a descendant of similar trees that flourished millions upon millions of years before the first ancestors of man appeared on the earth. The sequoia tree at the British Museum marks for us the progress of epochs within historical time; the maiden-hair tree carries us back to the unstoried days before man.

The humble insectivores play a similar

part in regard to the history of mammals. The tiniest mammal on earth is a shrew, but it represents a more ancient line than that of the lordly lion or the giant bear. For the insectivores were kin to the ancestors of the type from which all the carnivores rose. They lead on to the bats, winged insectivores, though bats are placed, of course, in an order of their own. The insectivores proper remain a distinct and peculiar group. While externally resembled by some other mammals, they are wholly distinct in anatomy, and preserve for us the mould in which Nature fashioned some of her earliest serious attempts at a mammalian type of life. It may be of service to note here that, because an animal occasionally eats insects, it is not necessarily an insectivore.

The true insectivore is a mammal distinguished by the peculiar character of its teeth. None of the teeth has the flattened grinding surface common to the molar teeth of the majority of animals, nor are the teeth of the insectivore so shaped as to work with the shear-like action characteristic of the carnivore's. The insectivore's teeth are furnished with sharp tubercles, enabling the animal readily to seize, hold, and pierce the body of insect, slug, or worm. In the structure of the insectivore there are anatomical traits readily distinguished by the man of science, but one external character strikes even the ordinary observer, and that is the long, narrow, mobile muzzle possessed by nearly all members of the order.

How the Weaker Animals Seek the Line of Least Resistance when Competition Becomes Keen

It is an immutable natural law that lower orders shall yield place to higher. Yet the insect-eaters have not vanished from the earth. They are found wherever there is a suitable food supply, except in Australia and South America, where their place is taken by marsupials. How, then, are we to reconcile this wide distribution of the insectivores with the afore-mentioned law? That law and the prosperity of the insectivores are not inconsistent. These lowly animals have not yielded up their lives, but they have yielded up their places to stronger, more intelligent, better-organised animals. They have sought life along the path of least resistance. In continental islands where hungry carnivores have not had to be faced, the struggle for existence has not been unduly acute.

Under less favourable conditions, however, the insectivores have adapted themselves to circumstances in special ways. Some of them have taken to the water, some have become tree-dwellers, some burrow underground; some, like the hedgehog, have put on armour, while the cobego has developed the best natural parachute in existence, and has advanced nearer to true flight than any animal, after the bats. The latter, as we have seen, rose from the insectivores, but not from any type now living; the connecting links were snapped in ancient days.

A Too Easy Life that Has Led the Cobego to Poor Development

The insectivores have very small brains, of the lowest quality, yet, apart from their economic value, they are not to be despised. A group of animals, first among the mammals evolved, which has kept itself alive and efficient through all the fierce conflicts of time, and still well holds its own in the hard struggle for existence, deserves very special consideration. It is an order of about 230 species; and when we find it comprising "flying" animals, swimming animals, mining and armoured animals, we cannot complain of lack of variety or interest.

The cobego's acquaintance we made on page 303, so we may dismiss it here with the reminder that though the best authorities now rank it with the true insectivores, there was for many years a tendency to place it in an order by itself. In the immature condition of its young at birth, it has affinities with the marsupials, but the wonder is that it never became a bat. A very slight process of evolution might have converted it into a flying fox, for, like those great bats, it appreciates a vegetable diet. Is it not strange to find a vegetable-eating insectivore? By what steps this animal was led to a life in the trees and to a diet consisting of leaves, with insects as quite an unimportant addition, it is impossible now to trace, but it looks as though the cobego has run into a blind alley of existence, and found no way out to better things. It does marvellously well with its parachute, and, content with that instrument, it has developed only an utterly contemptible brain.

An Animal that Once had Good Sight but is Giving it up as Unnecessary

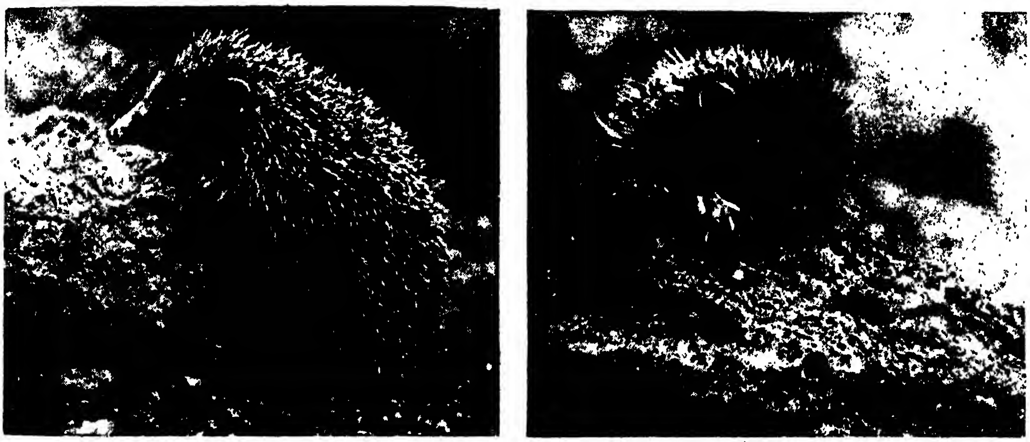
"As blind as a bat" is a common expression among people who do not realise that the bat has really excellent sight. "As blind as a mole" is a saying which incurs the censure of the countryman who happens to have seen the eyes of this denizen of the underways of the world. But if the mole

is not yet blind, it is rapidly falling into that lamentable condition. In the struggle for existence, this animal has been forced to burrow for a home and a living. We cannot tell, of course, how long its underground habit has prevailed, but the period must have been considerable. For the time is approaching when the eye of the mole will be as functionless as the pineal eye of man himself. So degenerate has the instrument of vision become in the European mole that, when the animal is skinned, the atrophied organ comes off with the hide. This condition has been brought about, it is surmised, not through any injurious effect of mining, but through the mole having, like the fish of unsunned caves, learned to depend upon smell and touch rather than on vision. This is a remarkable example of evolution in progress. In the embryo the eye of the mole is large; in the young mole it is larger than in the adult. The older the mole grows the smaller becomes its power of sight, until in the adult animal it is doubtful if the eye is more than sensitive to light. All this is extremely curious, seeing that the mole does not, as is commonly supposed, live entirely underground, but comes out at night, and sometimes by day, in pursuit of food.

But it is as a tunneller that the mole is chiefly interesting. For this work it is specially well adapted. Its forefoot is among the finest of natural excavating implements, being equipped with four fingers and a thumb of rare strength. It should, however, be noted that though the term "thumb" is employed, this digit cannot be opposed as can the thumb of a primate. Practically all the insectivores have five fingers to each fore limb, but none has the thumb opposable. The fur of the mole is ideally adapted to life in earthy tunnels. The hairs are set vertically, and turn in any direction, so that no soil can defile the animal's wonderful coat. Perhaps the lot of the mole might be happier were his coat not so impervious to soil, for he is infested, like the hedgehog, with fleas and mites. Poultry, as is well known, take dust-baths to rid themselves of parasites, but the mole, living in the soil, does not find the remedy efficacious. It might be interesting to ascertain whether the flea of the mole shows any special modification enabling it to withstand the effects of dust. Possibly the soil-grains are too coarse to clog the spiracles of the mole-flea.

Moles breed once a year, and the female gives birth to from two to seven young. Until quite recently it was believed that males greatly exceeded the number of females. This, however, proves to be a mistake, due to the fact that except at certain seasons there is a striking superficial resemblance between the two sexes. Males and females are now shown to be about equal in numbers. It would be serious for the underworld were the case otherwise, for even with the sexes equally divided battles between the males for the favours of the other sex remain fierce and deadly. Four or five males may assemble to battle for possession of a single female, a circumstance due to the fact that moles do not mate for life as do many of the higher mammals.

The fortresses of the mole and the



DESCENDANTS OF MAMMALS LIVING IN BRITAIN BEFORE THE BRITONS

The hedgehog, of which two pictures are shown here, is one of the oldest of the insectivorous animals. It has the meanest of brains, but its prickles, and the power to curl up in face of danger, have kept it alive where more highly organised animals have become extinct.

passages leading to them have long been famous as examples of animal architecture. The labours of one of these industrious animals led a careful observer to an interesting calculation. The work done by a mole in a single night in soil upon which rain had recently fallen was such that, in order to perform its equivalent, a man would have to excavate in a single night a tunnel thirty-seven miles long, and of sufficient size easily to admit the passage of his body.

The mole's so-called fortress is really the chamber in which it makes its nest. The nest, however, is not used as a nursery. The female makes a smaller fortress for the reception of her young; and it is not known whether she and the male share the same nesting cavity earlier. In making his tunnels the mole excavates with his forepaws, and thrusts the loose earth to the surface with the nose and the top of his head. Tunnels are frequently carried round the fortress, and may lead to an exit or entrance at some distance from the mound, while others are mere blind alleys. Not all the twistings and burrowings form part of a settled plan; the mole seems at times to excavate merely from habit, just as the prairie dog digs holes unnecessarily.

The Animal that is Hardest Worked Because it is the most Hungry and Thirsty

On the other hand, many of the passages which have been examined and declared useless may have been galleries dug in search of water. No creature is more intolerant of thirst than the mole. He must drink and eat repeatedly; it is said that he cannot endure hunger for longer than three hours at a stretch. It is his incessant hunting for food which makes him a nuisance in gardens and cultivated lands. He consumes an enormous number of harmful grubs and larvæ, but, where he has undermined, field mice can follow, to get at seed and damage crops. Still, take him for all in all, the mole has contributed enormously to the good of the land which civilised man has come to claim for his own.

The mole family extends far and wide. A strange member of the clan is the desman, which haunts the banks of rivers and lakes in South-Eastern Russia. Once it was part of the British fauna. With its long, trunk-like snout, its curiously flattened tail, and strong musky odour, the desman—or musk-rat, as it is sometimes wrongly called—is almost entirely aquatic, feeding on leeches and water insects, and rooting them out from weeds and mud with its muscular, mobile proboscis. Although its feet are webbed, it is a capital miner. The tunnel where it rests and brings forth its young runs as much as twenty feet into the banks of the stream in which it swims.

North America has a mole with webbed feet, which is called the web-footed mole. Naturally, then, it would be thought that this animal is essentially an aquatic variety. Such is not the case, however. The cause that may have led to the development of the webbed feet does not now exist. For this mole inhabits regions remote from running water, as the farmer whose crops its travels disturb only too well knows.

A Mole that Must Have Changed Its Habits as the Ages Have Passed By

The nearest relative of this misnamed mole—*Scalops aquaticus* is the scientific description of this animal that is not aquatic—is the hairy-tailed mole, and it is the link between the web-foot and the star-nosed mole. All these three groups are North American. The last-named is, as its name implies, distinguished by an extraordinary development of the muzzle. The snout, long and slender, has at its extremity a disc of soft, fleshy, rose-coloured rays, very sensitive and mobile. Numbering about a score, these radiate like the petals of a daisy or the tentacles of a sea anemone, and the nostrils appear in the middle of the disc. It can only be supposed that the purpose of this fleshy star is to help the animal in its search for worms and insects, yet there is no evidence that this animal enjoys any advantages over other moles in the matter of sensitiveness of touch.

Between moles and shrews there is an interesting link in the shrew-mole, of which there are two known species, found respectively in Japan and America. The Japanese species has never had to go to ground. Hence it has not developed the mining tools of the mole, but retains the narrow clawed paws of the running animal. In appearance it resembles a shrew-mouse, but its head and teeth are those of a mole.

An Ancient Type of Animal that Persists Through Passive Resistance

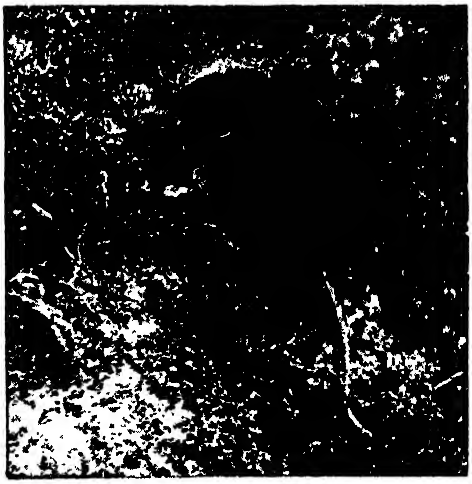
The hedgehog is the king of British insectivores. Men may come and men may go, but the hedgehog, unless his territory be built over, goes on for ever. He is one of the most ancient of existing mammals, very little altered to-day from the hedgehogs of millions of years ago. It is doubtful whether his mail of prickly spines was first evolved as armour; but as so many animals have adopted protective devices of this sort, we cannot be wrong in assuming

that defence, and not adornment, was the purpose of the urchin's formidable great-coat. Most of the armoured animals have gone, but the hedgehog flourishes still. He has never been driven underground, or to the water, or to the trees. His prickles, and his ability to curl himself into a ball of spikes, added to his faculty of going to sleep for the winter, have kept him safe and prosperous. His diet is chiefly insectivorous, but he will eat snakes and frogs, mice and young moles, and, it is said, young birds and eggs. His attacks upon the nests of birds have been hotly debated. Undoubtedly the hedgehog has been found devouring the eggs of ground-nesting birds, but it has not been proved that he himself broke the eggs. His apologists aver that a rat must have been before him to shatter the shells.

the spines begin to develop and harden. A nest of leaves or the root of a tree, or the shelter of some hidden clump of soil or turf, suffices for a home. At least three generations of hedgehogs sleep beneath the floor of a summer-house at the present writer's home.

The study of this family throws interesting sidelights on the struggle for existence which even these well-favoured animals undergo. In addition to the insect resources of a garden of three acres or so, they find an additional food supply in the thousands of young frogs reared every spring within the boundaries of their home. All they have to do is to eat and drink and make the best of life. There are only two pitfalls in the garden, yet both have been near the undoing of hedgehogs. One is a miniature lake

THE PIGMY SHREW



THE COMMON SHREW

The pigmy shrew (on the left) is the tiniest of British mammals. The common shrew is larger, though only 2¾ inches in length. Both animals, though mouse-like in appearance, are purely insectivorous.

Another crime laid to his charge is that of sucking the milk of cows. As the udder of a cow is highly sensitive, we have only to calculate what would be the effect of contact with the intensely sharp prickles of the hedgehog to see how much truth there is in this wild allegation. That the hedgehog likes milk the present writer has frequently proved. But he likes minced beef, too, and cooked vegetables, and soaked bread. Surely he is not on that account to be charged with robbing the butcher, the gardener, and the baker!

The female hedgehog gives birth to four, five, even six young, and, her first litter being born in May or June, a second family may appear in October. The young are born blind, naked, and smooth, and their power to curl themselves up does not appear until

which is more easily entered than left. With abundance of water elsewhere, a hedgehog blundered in and was rescued at almost its last gasp.

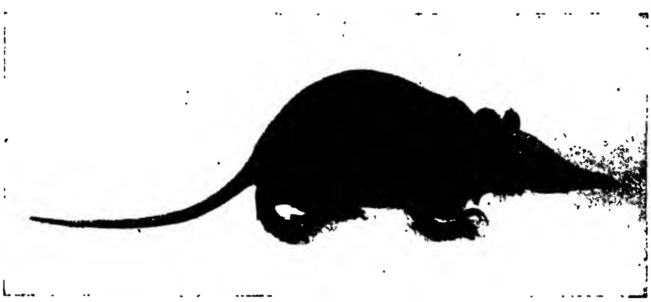
The second pitfall should be the most futile of traps, but it is not. From the hedgehogs' home extends a wide, thickly planted shrubbery, running half way round the garden, making a natural covered way for them to the centre whence all the frogs radiate. Now, in this shrubbery a slight step drops down from a gravel path to a wicket gate. It is only nine inches deep at the lowest point, yet hedgehogs, more than half grown, blunder in and cannot get out.

In previous years one or two had been taken out, with no thought of rescuing them from peril, but simply that they might be

kept and fed and petted for a day or so. But last year two were found lying there, upon a little bed of drifted leaves; so, instead of being removed, they were fed where they were. A supply of bread-and-milk and meat was deposited, and the little urchins were left to go where they chose. To make quite certain that they should be able to get out if they desired, the writer built up a little mound of stones, enabling them easily to reach the upper ground. The animals were not visited for another couple of days. They were still there—*prisoners.*

In spite of their sharp claws, they could not scale the nine-inch wall, rough and favourable for climbing as it was. And they had not sense enough to take advantage of the mound of stones. The bottom of the wicket gate was polished where they had rubbed it as they ran to and fro, seeking a way out. One of the hedgehogs was slightly larger than the other; he was now bright and active, but the other was almost dead. The struggle for existence had been in progress here. The larger and stronger animal had claimed the food, and the weaker had gone to the wall. The lustier animal fed ravenously at once. The smaller one, though it had been very timid when in good health, now made a pathetic attempt to crawl to the writer's hand, but was so feeble that it had to be lifted, and so far gone that it could neither bite nor lap. It just managed to lick a little milk from the finger. Placed before a fire and frequently coaxed to feed in this manner, it revived in the course of a few hours, and next day banqueted regally on worms and minced beef.

That is the sort of thing that is happening every day. Many hedgehogs follow the path through the shrubbery, but only those with the least active brains drop down that step, or, if they so descend, they have wit enough to climb out. The least adaptable remain to die, unless chance brings a human rescuer. And when two are prisoners together, the stronger takes the food from his fellow, and the weaker suffers. That sunken step in a Kentish garden reveals, in miniature, a pregnant chapter from the story of the struggle for existence wherein the whole animal world is daily engaged. The hedgehog is the only wild animal left in that garden. Occasionally a stoat, a rabbit, a rat, a field mouse, or a vole appears, but the hedgehogs are the sole remnants of the indigenous fauna. Their forebears were there when Julius Cæsar waged war on the summit of the hill, yet this little trap is too much for the descendants of the resident patriarchs. Bristles, not brains, keep our hedgehogs alive



A RAT-LIKE INSECT EATER; THE SOLENODON

The solenodon, found only in Cuba and Haiti, has, as its nearest kin, the tenrec of distant Madagascar.

When we seek the nearest relations of the hedgehog it is a little surprising to find them in rat-like animals, the gymnuras, or rat-shrews. The latter name relates to the external characters of these animals, but their teeth and internal structure show them to be closely allied to the hedgehog. They are natives of Burma, the Malay region, the Philippines, and part of China. There are several species, some as big as good-sized rats, others as small as mice. All are purely insectivorous. The discovery of fossil remains of an extinct genus of gymnura in France is cited as evidence of the similarity of the fauna of Europe in ancient days to that of the present-day Malay Archipelago.

The most numerous and widely distributed of all the insectivores are the shrews. Upwards of 120 species of them have been identified. Many are excessively local in their range. We can but glance at a few of the best-known examples. The first are the tupais, or tree-shrews, which, like the cobego, live in Oriental lands. In their general external outline they so nearly resemble squirrels as frequently to be mistaken for those animals. But the head, with its elongated muzzle, is typical of the insectivore, and the character of the teeth is unmistakable. Though driven to find shelter in the trees, the tupais descend to the ground under the whip of hunger, and they will even venture into human dwellings, where they are easily tamed. The jumping shrews, also called elephant shrews, by reason of the trunk-like extension of their snouts, are the African representatives of

the tupais. They are ground animals, and move by leaps, after the fashion of the kangaroo.

Although the jumping shrews are restricted to Africa, there are many species of them. Some haunt the thick undergrowth; others dwell in stony wastes, where clefts and crannies in the rocks offer secure asylum during the dreaded hours of daylight.

The pretty little shrew-mouse suffers from its superficial resemblance to a mouse or small rat. But its long, pointed snout and small, rounded ears should be sufficient to save it from a miscarriage of justice, even if the distinctive teeth are overlooked. It has long been a much-misunderstood animal. If it escapes from being confused with a noxious rodent, it may still fall a victim to the extraordinary superstition that the shrew-mouse's bite is poisonous, and that if it merely touches man or animal the part against which it brushes is doomed to paralysis. The tradition is old, the origin not to be traced, unless it be that the little beast is terribly pugnacious in opposition to its own kind, and that it emits an unpleasant smell. The truth is that the shrew-mouse is one of the very best friends of the gardener. It destroys immense numbers of insects, snails, worms—the last, a thing rather to be deplored—and field mice. England and southern Scotland possess two species of a water-shrew, which is common to the greater part of Europe.

China, however, has an aquatic shrew which has specialised more than any of its relatives. This, the web-footed shrew, has the soles of its feet furnished with disc-like pads, to enable the animal securely to grip the surface of smooth stones and rock as it seeks its food at the bottom of the water. The musk shrews, unknown in Britain, are widely distributed throughout Asia and Africa. One kind, the grey musk shrew, is among the plagues of Indian households. Yet, in spite of the fact that it leaves an offensive musky trail, it almost earns its house-room by the vigour with which it pursues the noxious insects that plague the white man.

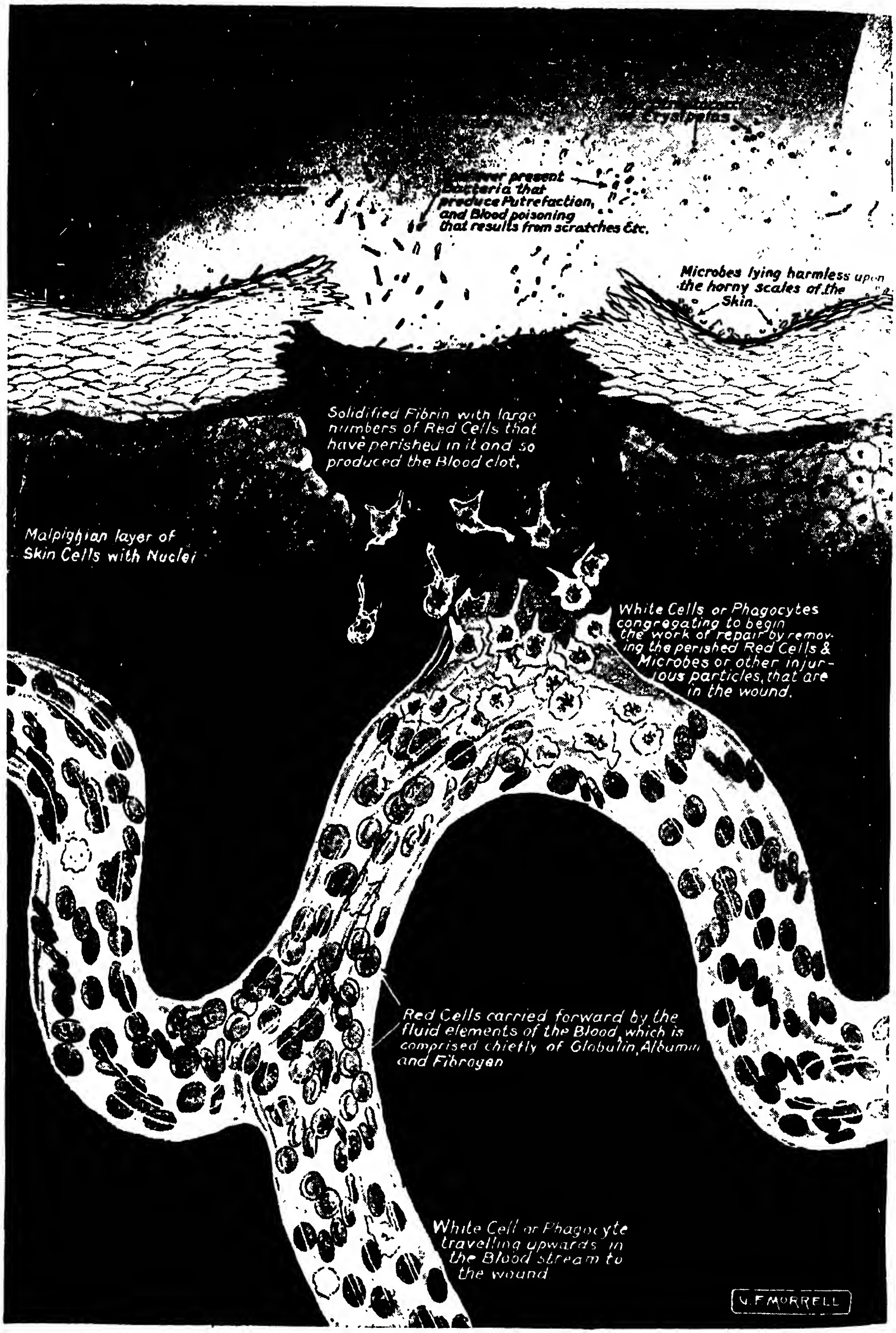
A few of the other curious insect-eaters are worthy of remark. The first pair are the tenrecs and the solenodons. The former are natives of Madagascar, the latter of the West Indies. Their distribution is as interesting as that of the tapirs, and tells of ancient land connections which have vanished under the seas. The great tenrec is the most formidable beast of the whole order. Tailless, he attains a length of 16in. and considerable size, and possesses such teeth as enable him to inflict a serious bite. His diet consists almost entirely of earth-worms, which he comes out only at night to seek. Yet to secure himself from attack the tenrec has found it necessary to evolve a mixed armour of bristles, hair, and spines. A smaller species has spines resembling those of the hedgehog, and is called the hedgehog-tenrec. One tenrec has become aquatic; and yet another, the rice-tenrec, carries its search for insects beneath the roots of growing rice to such lengths as to become a greater menace to agriculture than the pests of which it is in quest. The tenrec is one of the most prolific of all animals, twenty-one at a birth having been stated to occur. The solenodons are long-snouted, powerful-clawed cousins of the tenrecs. Wide as is the gap geographically between the two species, they are closely related.

THE TENREC OF MADAGASCAR

Tenrecs are peculiar to Madagascar, where, when their diet of insects fails, they become torpid for the hottest part of the year.

The otter-shrew finds a place among the insectivores by virtue of the insectivorous character of its teeth. The muzzle is broad, not pointed after the fashion of other animals of his order; and this expert swimmer's habits in general, and of fish-taking in particular, decidedly suggest the otter rather than the shrew; while its skeletal characters are different from those of all other members of the order, in that it lacks collar-bones. This animal is referred to a distinct family. The golden moles constitute another. "Golden mole" is the local name, but the animal is more nearly related in structure to the tenrec than to the mole. Still, in habits it is clearly mole-like, burrowing and tunnelling in search of worms and insects after the fashion of our own little subterranean workmen. It gets its name "golden" from the rich metallic lustre of its fur.

THE HEALING POWERS OF THE BLOOD



THE SENTINELS OF THE BLOOD: HEALING A TINY WOUND AND DESTROYING THE INVADING MICROBES

This picture-diagram represents a section of the skin, about one-sixtieth of an inch thick, with a tiny scratch sufficient only to tear open one minute capillary. On the one hand are shown the dangers from various forms of septic bacteria ever present in the air, and in contrast the marvellous provision of the blood and its many elements to protect the body by destroying intruders and healing the wound. The phagocytes effect this healing by transforming the element fibrinogen into the solid fibrin of the blood-clot. For the sake of clearness the capillary and the red and white blood-cells within it are drawn larger in proportion than the tissues of the skin.

THE PULSING STREAM OF LIFE

Living Blood Always Travelling and Constantly Transformed Carries the Body's Supplies and Repairs its Defences

A MAN'S BLOOD PERSONAL AS HIS FACE

The body of man, like that of most animals, is provided with a complicated mechanism, of pump and tubes and nerves, for the circulation of a fluid called the blood. If the circulation ceases for more than a few seconds we die. Thus, though there is no real meaning in the familiar phrase that "The blood is the life," the blood is necessary to life, and, further, its continuous motion is necessary to life. We may add that the blood is itself alive. Though it is fluid, and not a tissue, such as muscle or brain tissue, yet it comprises living cells as they do, and in quite as high a proportion to the rest of its composition. Its living cells do not enter into any mutual relation, and are not fixed, so that we cannot exactly call the blood a tissue; yet it is at least as crammed with life as any tissue or organ of the body, and we should beware of being deceived by its fluidity. The blood can become a solid at any time, and is never more valuable and more alive than when it does so. A portion of solid or clotted blood, actively engaged in reparative and constructive work—a tissue-maker, indeed—cannot possibly be denied the title of a living tissue which we grant to brain, or gland, or muscle.

There is a marked contrast in this respect between blood and such a fluid as milk, which is manufactured from the blood. The fluidity of both is deceptive, and only for convenience. Each can readily be solidified, and in that form gives us a much better idea of what it really is than when it is in the fluid state. We then realise that each contains a quantity of solids dissolved in water, which is true of all tissues. But though milk contains globules of fat it contains no living cells; and solidified or clotted milk cannot be called a living tissue, nor liquid milk a "vital fluid," as is too commonly done. Clotted blood, on the other hand, such as binds and repairs a wound, is a living tissue, if anything is; and liquid blood is a "vital fluid," in the fullest sense of the words, so long as we do not mean that the fluid part of the blood, in which its cells swim, is itself alive.

We cannot contemplate the circulation without guessing that the fluid which requires to be unceasingly moved on is so moved in order to undergo changes. Evidently something must happen to it. If, for instance, every red blood-cell must pass through the lungs, say once a minute, it must either give or get something there, and be thus different according to whether we examine it in a pulmonary artery or a pulmonary vein. This general assumption about the circulation of the blood is proved by the simple observation that the blood in an artery and the blood in a vein differ in colour. So marked and important is the difference that we speak of arterial blood and venous blood, the former being bright and red in colour, while the latter is duller and of a red which is all but blue. We observe the colour of venous blood in the face of anyone whose venous circulation is being obstructed by great cold or heart-disease, or fury, or even a tight collar. Plainly, therefore, there is some radical distinction between arterial and venous blood, and we cannot describe "the blood" as if it were a single, constant fluid.

If we had the opportunity of examining the blood in the pulmonary artery going to the lung, and in a pulmonary vein returning from the lung, we should further discover the notable fact that these vessels are exceptions to our rule. They are, respectively, artery and vein, beyond a doubt, because of their structure, and because the one leads from and the other to the heart. But we find that the pulmonary artery invariably contains venous blood, as we have agreed

to call it, and the pulmonary veins contain arterial blood. If we remember the course of the circulation we see that this must be so, for the blood in the pulmonary artery is that which, a second before, entered the right auricle from *veins*, and is thus still venous, while that in the pulmonary veins will in a second be passing through the left auricle and ventricle into the prime artery called the aorta. Thus the definition of the two kinds of blood as arterial and venous is really accurate only in reference to the arteries and veins of the greater or systemic circulation; in the lesser or pulmonary circulation the facts are reversed. And the evident meaning of this must be that, in flowing through the capillaries of the body generally, arterial blood becomes venous, bright becomes dark, and, in flowing through the capillaries of the lungs, venous blood becomes arterial, dark becomes bright.

This is only the most evident and familiar illustration of the general truth that the blood is constantly altering in composition and quality as it passes through any capillaries anywhere, in consequence, evidently, of that all-essential leakage, in both directions, for which capillaries and the circulation of the blood exist.

The Changes that take place in the Blood While it is Passing through the Tissues

The blood that enters the liver, for instance, is a different fluid from that which leaves it. Not only is the blood that leaves the liver hotter, but it has been deprived of various constituents, and has acquired others; while even the number and quality of its red cells are altered. Again, the composition of the blood returning from the bowel after a meal is notably different from that of blood returning from the same capillaries before a meal; and the proportion of white cells in the blood after leaving the spleen and various other parts of the body must be greater than before; while young red cells, as we have already seen, will be more abundant in the capillaries leaving red bone-marrow than in those entering it. Thus the blood is not only a living tissue, from one point of view, its fluidity and movement notwithstanding, but it is also the great medium of exchange of the body, and its composition is modifiable, and, indeed, in many respects *must* be modified, from moment to moment, as regards every fluid constituent, and the number, kind, and age of its living cells.

Yet, on the whole, the blood has constant properties; and nothing is more characteristic of it than its unfailing resource in keeping them constant. Its proportion of water, and of each and many salts, its specific gravity and temperature, the number and kind of its cells—all these remain, on the whole, amazingly constant in all vicissitudes. The great changes from arterial to venous blood and back again are rhythmical; the changes due to meals are transitory; those due to addition of new cells to replace old ones are only local, and do not permanently affect the general composition of the blood.

The Blood the Most Mutable and Unstable Fluid in the World

Normally, therefore, we can describe certain very constant facts of a typical drop of blood; and this we may proceed to do if we remember, from the first, that, with all its constancy, this is also the most mutable and unstable and sensitive fluid in the world, and must be so if it is to live and serve the life of the body.

The cells of the blood are of two kinds, red and white. Further subdivision is possible, but this is the great and obvious difference, and no one can hesitate to describe any blood-cell as belonging to one or other class. The red cells are without a nucleus, unlike the white ones, but even the occasional presence of nucleated red cells in the blood can cause no confusion, for their destiny, colour, and category are obvious. The red cells are formed in the marrow of the bones. When formed, by the cell-division which is the same here as elsewhere, of course they have nuclei, like every other cell in the body at some stage or other.

How the Blood Alters itself to Meet any New Demand made on it

But as these cells are highly specialised for a single function, which requires no nucleus, and as, indeed, the nucleus would take up room which is required for the packing of other things, it disappears at once, so that nucleated red cells are never found in normal blood. But if the blood be undergoing serious loss or damage of its red cells, as often occurs by accident or disease, we shall at once find nucleated red cells in it, showing how promptly and with what haste the body seeks to right the composition of its blood.

The red cells, when studied singly, are found to be yellow rather than red, but their enormous concentration produces the effect of red. The colour is due to the one constituent for which the cells exist. Otherwise they have no powers or duties.

They are circular, bi-concave discs, with an invisible elastic envelope, no internal structure, no trace of anything like their young nucleus, and no power of movement. We cannot call them dead, but they are very little alive. The disappearance of the nucleus proves that; and there is no sign of any capacity for response or spontaneous action, much less reproduction, in red blood-cells. In all these respects their simple, passive, mechanical nature contrasts them sharply with the white cells. They exist simply in order to carry the red—or yellow—colouring matter, which is called hæmoglobin.

The most Complex Substance Known to Chemistry Manufactured for the Blood

The adult red cell is thus simply a porter, nothing more. But in its youth, and especially in its origin, it is far more, for the manufacture of the hæmoglobin is a great chemical feat; and when the new red cell is made its hæmoglobin is made also. This substance is the most complex known to chemistry. It is a compound of many elements, and is built up by the association of many lesser compounds, into which it can easily be split. It is estimated that the molecule of hæmoglobin—the smallest quantity of it that can exist as such—must contain not less than a thousand atoms, and this molecule is not only the most complex, but the largest, that chemistry knows. We should not under-estimate the chemical skill, thus proved to be transcendent, of the cells in the red bone-marrow where hæmoglobin is made.

"The colour of life" is due to this compound. It colours the blood, and supplies the material for colour in many other fluids and tissues of the body. As we might guess, from our knowledge of the chemistry of iron and its compounds, hæmoglobin contains this metal; it is, indeed, "a compound of iron," apparently containing one atom of iron in each of its enormous and many-atomed molecules. But though the iron constitutes, perhaps, less than one-thousandth part of hæmoglobin, it is essential not only for its colour, but for its existence, and therefore for the body's existence.

Curious Parallels Between the Fluids Circulating in Man and in Plants

We can further study the chemistry of hæmoglobin in blood that has been shed in the tissues or elsewhere—for instance, in a "black eye." We find that this huge molecule breaks up into two parts called hæmatin and globin, the former containing the iron and being crystalline, while the latter belongs rather to the group of the albumins or proteins. Numerous further changes are possible, with variety of colour, such as we see in a black eye when it turns green and yellow. But the chemistry of this all but unparalleled compound is a matter for the expert, beyond such a point as this.

One parallel it has—the chlorophyll or green substance found in the leaves and other parts of plants. This compound is also coloured, very complicated in structure, and must always contain iron. In the absence of iron, as food for plant or any creature that has red blood, such as man, these compounds cannot be formed, and the life must fail. Chlorophyll and hæmoglobin are equally widespread in the plant and animal world, above a certain humble level in each case, respectively. Each has an all-important function concerned with oxygen, the chlorophyll of the plant being the means of taking carbon from carbonic acid by separating it from the oxygen in that compound, and thus leading to the formation of carbonaceous foods for man and other creatures like him to burn and live by. This they do by combining them again with oxygen, which hæmoglobin carries from their lungs to their tissues.

An Old Name given by the Greeks that accidentally Conveyed Scientific Truths

Thus, in a sense, and considering life as a whole, chlorophyll and hæmoglobin are equal and opposite in their action; and the parallel is completed by the recent chemical study of chlorophyll, which has brought out its remarkable chemical similarity to hæmoglobin.

These large considerations, though so general, tell us what happens in the body of man. We say that the red blood-cells are simply the mechanical conveyers of hæmoglobin, but we must go on to note that this hæmoglobin becomes changed as they carry it. The change appears to be purely a physico-chemical one, and not due to any vital activity of the red cells. The hæmoglobin we have described is a comparatively dark-red compound, and we find it only in venous blood. When this blood returns from the lungs by the pulmonary veins it is brightened, and no longer contains any hæmoglobin as such. For each molecule of hæmoglobin has now added to itself two atoms—that is, one molecule—of oxygen gas, forming a new compound, called oxy-hæmoglobin. This is brighter in colour, and is a true, though loose, compound, as we can prove by studying its spectrum. Specimens of blood containing hæmoglobin

and oxy-hæmoglobin respectively produce different effects upon light transmitted through them, as we see when we look at them through a spectroscope. This spectroscopic examination of the blood is important, also, from the medico-legal point of view, as it may determine the cause of death from asphyxia, as also death due to gas-poisoning in sewers or coal-mines.

In sum, then, the hæmoglobin of the blood becomes oxy-hæmoglobin in the capillaries of the lungs, and this oxy-hæmoglobin is reduced to hæmoglobin again in the capillaries of the body. We have here the explanation of the pulmonary or lesser circulation; and we learn, also, that the term artery, or "air-carrier," is not quite a misnomer after all, since the arteries do carry air, or its chief constituent, from the lungs to the tissues, in this fashion.

Why Anæmic People are Given Iron by the Doctor in their Medicine

Oxygen is always found dissolved in the fluid of the blood, but such solution could never begin to be adequate for the needs of the body. The virtue of oxy-hæmoglobin lies in the extraordinary condensation of oxygen which it makes possible, and that is the virtue of the red cells. No wonder that the anæmic girl is easily made out of breath, for she has too few red cells, and too little hæmoglobin in what she has. No wonder, also, that the number of these cells is so great—from four to six millions in a volume of blood equal to two pins' heads, but markedly fewer in women than in men. Only in such numbers can they convey enough oxygen for the purposes of the tissues. There is reason to believe that their lives are brief, probably lasting only a few weeks. Thus they must be incessantly produced in enormous numbers, a process which involves the ceaseless activity of the bone-marrow and a continual supply of iron in the food. The cells that are worn out appear to be broken up chiefly in the liver, though also, probably, in the spleen and elsewhere; and it is from the colouring matter of the effete cells destroyed in the liver that the bile obtains its colour. The colour of the secretion of the kidneys is also derived from broken-down yellow-red cells.

Some of the Unsolved Problems of the Constituents of the Blood

Why the lives of these cells, whose function is so simple, should be so brief, involving such incessant replacement of them, is not obvious, but the writer would suggest that they are already doomed to early death when they lose their nuclei, and that it is this early loss which determines the shortness of their lives thereafter. The cells of the skin similarly lose their nuclei, and perform the mechanical function of protection, but they die soon afterwards, and are replaced from below.

The blood also contains a large number of minute flat objects, called blood-plates, which have no visible structure, and are not cells—at any rate, so far as we can observe them—and of which at present we do not know, and cannot even guess, the function.

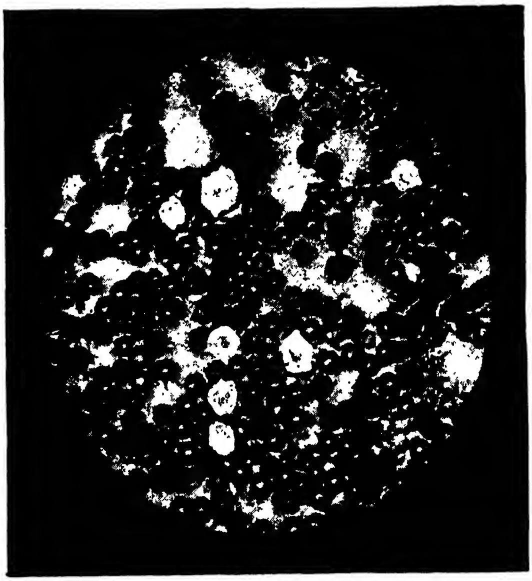
Much less numerous than the blood-plates, but of proved and understood importance, are the white cells. These constitute the third and last of the organised elements of the blood. They present almost every possible contrast to the red cells. They are relatively very few, in health, the blood containing not more than 9000 or 10,000 for every 5,000,000 of the red cells. In certain conditions the numbers are diminished, as in chronic alcoholism, and in a multitude of other conditions their numbers are greatly increased, for a purpose lately discovered. Their lives cannot be very long, but we do not know where, nor how, they die and are disposed of in health. Though they possess nuclei, they do not multiply in the blood. Their source and origin can be traced when we study their different forms.

Cells that act as Guardians of the Body and eat Harmful Intruders

For, unlike the red cells, these white cells or leucocytes are of many different types. Students of the blood are not yet agreed as to the relation between them, but it is certain that some of these types are younger and less mature forms of others. Though all have nuclei, these nuclei stain differently in different types, some being shown up by acid and others by alkaline dyes. This indicates a radical chemical difference between them. The most numerous form have a large, very irregular nucleus, of such a shape that it was long thought to be several nuclei, and these were called multi-nuclear leucocytes. It is almost certain that these represent the fully mature and active state of another type, smaller, rounder, and having a large spherical nucleus that almost fills the cell. These appear to do no work, and probably they change into the larger and more numerous kind as they grow older. The smaller, regular-shaped cells are called lymphocytes, and we know, for certain, that they are added to the blood as it passes through what is called lymphoid tissue, in many parts of the body.

This lymphoid tissue, examined under the microscope, is found to consist of little more than a dense multitude of round, young cells, which are about to become lymphocytes, and to be added to the blood-stream. When we learn the function which these cells will develop we need not be surprised that microbes, cancer-cells, and other enemies of the body are often arrested and attacked in lymphatic glands, nor at the fact that, in such a disease as malaria, the spleen is so greatly enlarged. The surgeon may often be inclined to wish that there were no glands in the neck, to swell with tuberculosis, and require removal, but if we look into the principles of bodily construction we learn that the lymphatic glands are, in many instances, the body's first line of defence; and it is much better that dangerous microbes, or cancer-cells, should be arrested and have to be dealt with in them than that they should pass on unchallenged to more vital and indispensable organs.

The function of the leucocytes has long been a puzzle, but the pioneer work of Lord Lister on inflammation, and the later researches of Prof. Metchnikoff, have answered the question in the most remarkable way. Lister found that a drop of pus or "matter," formed in inflammation, contains many dead leucocytes, though no blood-vessel may have been damaged. Metchnikoff studied the behaviour of certain cells in a minute organism called the water-flea, and in due course the facts were discovered. The actual passage of leucocytes of certain kinds through the walls of blood-vessels has been observed, and we know now why Lord Lister found them in pus. They have also been observed to do very real things inside the blood-vessels in certain invasions of the blood, and hence Metchnikoff has given to the mature form of leucocyte the name of phagocyte or "eating-cell."



A FEW WHITE CORPUSCLES OF THE BLOOD, TOGETHER WITH A NUMBER OF RED CORPUSCLES
Enlarged about 1000 times in a microphotograph by Mr. A. E. Smith

Whether the leucocytes have any function worth mentioning in health has long been doubted, but probably some of them do help to convey particles of food from the bowel to the body generally. But, for the rest, their function in health is like that of the sentinel or the policeman in times of peace and order. They are simply patrolling the body politic. If enemies enter the blood itself, as the parasite of malaria does, they are eaten there; if they do not enter the blood itself, the phagocytes leave the blood-stream and pursue them in the tissues, as marines may disembark and fight upon the land. We have seen elsewhere that the capillaries leak in both directions, and we have had reason to infer that they leak both gases and fluids. But they are also capable of being traversed by the phagocytes, very slowly and with much labour, so that not a single red cell follows and is lost—for red cells are only useful in the blood. This "emigration of the leucocytes" evidences a vastly higher capacity of sensation, and of devotion, than if they merely repelled invaders in the blood. It depends, as their actual eating does, upon their power of independent movement, called amœboid, or amœba-like, because of its resemblance to the behaviour of the amœba, which mature leucocytes resemble in so many other ways. But leucocytes are human, nevertheless, and exist for the body which they belong to, and which gave them birth. There is a form of amœba which is parasitic in man, producing the dread disease dysentery; and in such cases we see fight between the amœba that is an amœba, and the human cell which has assumed, or resumed, the form and behaviour of the amœba for the purposes of man.

One most notable fact of the behaviour of the white cells must be noted. Wherever the body is threatened they multiply to

an incredible extent, for the purpose of its protection. When injurious microbes make an entry into a wound, or otherwise, the whole body, as a single and devoted organism, wholly organised, coordinated, and mobile, devotes itself to the business of defeating them. No portion of the human commonwealth is out of touch with the rest; none is more immediately and whole-heartedly served than another. The danger may threaten in the brain, or the valves of the heart, or under a toenail. The same devotion, sacrifice, efficiency, concentration of purpose are found in every case.

The Three Gases that are Dissolved in our Blood, with Good and Bad Effects

Here we need only note further that the call to arms is not nervous, but chemical. Products of the local conflict, wherever it be, enter the blood and are carried everywhere, stimulating the production of new leucocytes in every portion of lymphoid tissue in the body.

We turn now to the fluid part of the blood, and may conveniently begin with three gases which we find dissolved in it. They are nitrogen, oxygen, and carbonic acid. The nitrogen has been absorbed from the air in the lungs, and does nothing in the body; and the same is probably true of the rarer atmospheric gases, such as argon, which would doubtless be found in the blood if they were looked for. The oxygen and its carriage we already understand, for that depends upon the red cells. The carbonic acid remains, and we must trace its carriage and destiny, in the blood, as the correlative to that of oxygen. We found that one of the differences between arterial and venous blood is that the red cells of the former contain oxy-hæmoglobin, and of the latter hæmoglobin. Similarly we find that arterial blood has no carbonic acid dissolved in it, but venous blood has. It is thus only in this degree that carbonic acid is one of the gases of the blood, and we may add that venous blood has no oxygen dissolved in its fluid part. The warning as to general statements of the composition of "the blood" is thus again justified.

The Delicate Chemical Balance that keeps the Blood Purified and Reinvigorated

The cells of the blood appear to take no part whatever in the carriage of carbonic acid from the tissues to the lungs. The whole of this work is done by the fluid, which, we noted, was inadequate to dissolve as much oxygen as the tissues need. But, on the whole, the oxygen carried in one direction and the carbonic acid carried in the other are comparable, and, indeed, the fluid of the blood could not dissolve the carbonic acid which it must convey. An exactly similar solution of the problem is obtained as in the case of the oxygen. The carbonic acid gas unites to form a loose compound with certain salts of the blood, especially sodium carbonate, forming a bicarbonate, as it is called, in venous blood—*i.e.*, a salt containing twice as much carbonic acid as a carbonate does. In this way the carbonic acid can be tightly enough packed; and just as the oxygen dissolved in the fluid of arterial blood is only a small proportion of what it really conveys, so the carbonic acid dissolved as such in the fluid of venous blood is a trifle compared with what the carbonates of the blood are carrying in loose union with them.

In the capillaries of the tissues generally, carbonic acid, formed by their life as in the burning of any ordinary fire, is absorbed by the blood, more or less balancing its loss of oxygen to the tissues. In the former case carbonates become bicarbonates, and simultaneously oxy-hæmoglobin becomes hæmoglobin, and the tissues gain oxygen. Exactly the reverse of both of these processes obtains in the capillaries of the lungs.

The Blood in a Man's Veins as Individual to him as his Features

We shall soon have to study the lungs and the process of respiration; meanwhile we note that the interchange of gases observed in the capillaries of the tissues generally is the *real* breathing, or "tissue-respiration," as it is called. It is for this tissue-respiration that we breathe, and for the lack of it that we die if the circulation of the blood ceases. Death from heart failure, no less than from drowning, is thus death from suffocation or lack of air.

The chemistry of the fluid of the blood is a profound subject, still in its infancy. We have lately found that not only is its composition different in different species and races, but actually that the fluid part of the blood is unique in every individual—personal and peculiar as his face and his ways. So there is room for study. But many facts are common to all men. The blood contains a quantity of water—which it is always losing and which must therefore be always replaced. We drink water in order to maintain the due proportion of it in the blood. In this water are dissolved,

besides the gases named, a multitude of other substances, which have much interplay between them, so that the problem is as complicated as that of the composition of sea water—and a thousand times more so. The constituents vary in complexity from peculiar proteins, called blood-albumin and blood-globulin, to such familiar but no less essential salts as sodium chloride, or common salt, which is necessary for various reasons, as that without it the globulin of the blood would coagulate. The albumin and globulin of the blood are in incessant distribution to the tissues to replace their ever-wasting substance, and require frequent replacement by the food.

The Element in the Blood that rushes to the Rescue as soon as anything goes Wrong

We consume albumin in milk, white of egg, meat, bread, and so forth, but none of these is blood-albumin, and they all require to be changed into blood-albumin if they are to enter the blood. If egg-albumin be injected into the blood-stream it acts as a poison, and is removed as soon as possible. These facts of the blood give us some preliminary idea of what digestion involves.

A third protein of the blood is not in incessant distribution. It is not for food purposes. Its name is fibrinogen—*i.e.*, fibrin-maker; and its function, like that of the leucocytes, is not for normal states of the body, but for its restoration to the normal when things go wrong. From the standpoint of heredity and the adaptation of the body, nothing is more wonderful than the presence of this compound in the blood, for no purpose but to solidify, if hæmorrhage should occur, and thus to arrest it. On what may be called the conventional scientific view of the origin of the body, such a purposeful provision as this is so utterly inexplicable that the explanation becomes ludicrously inadequate.

The Healing Processes that may be seen where the Blood Clots after an Accident

So long as the body leads its normal existence, the fibrinogen does nothing. But let a capillary be torn, and at once the blood solidifies around it and exemplifies the "natural arrest of hæmorrhage." This familiar process of blood-clotting is a series of marvels. The fibrinogen, which must, of course, be fluid when it is not wanted, undergoes chemical change, converting it into solid fibrin, by the action of a ferment in the blood, called the fibrin-ferment. But if this ferment always existed in the blood it would form fibrin and arrest the circulation. Therefore it only exists in undisturbed blood in the form of a pro-ferment, as it is called, and only when it is needed is it fully formed. Salts of lime are concerned in its extempore formation, but its real source appears to be those handiest of "handy men," the leucocytes. As usual in emergencies, they come to the rescue, the fibrin-ferment is formed, the fibrin follows, the breach in the vessel is sooner or later closed, unless it be enormous; and by a series of subsequent processes, which involve the whole physiology of repair, the fibrin and the leucocytes build up new tissue and mend the torn vessel.

The blood has lately been shown to contain many more compounds chemically resembling these three—the "hormones," which stimulate one tissue or organ, having been produced and added to the blood by another; the "opsonins," which, as the name implies, cook microbes and help to make them eatable by the phagocytes; and various "antitoxins" and "immunity" agents, which protect the body from, say, small-pox, having been added to the blood in the processes which are started by vaccination.

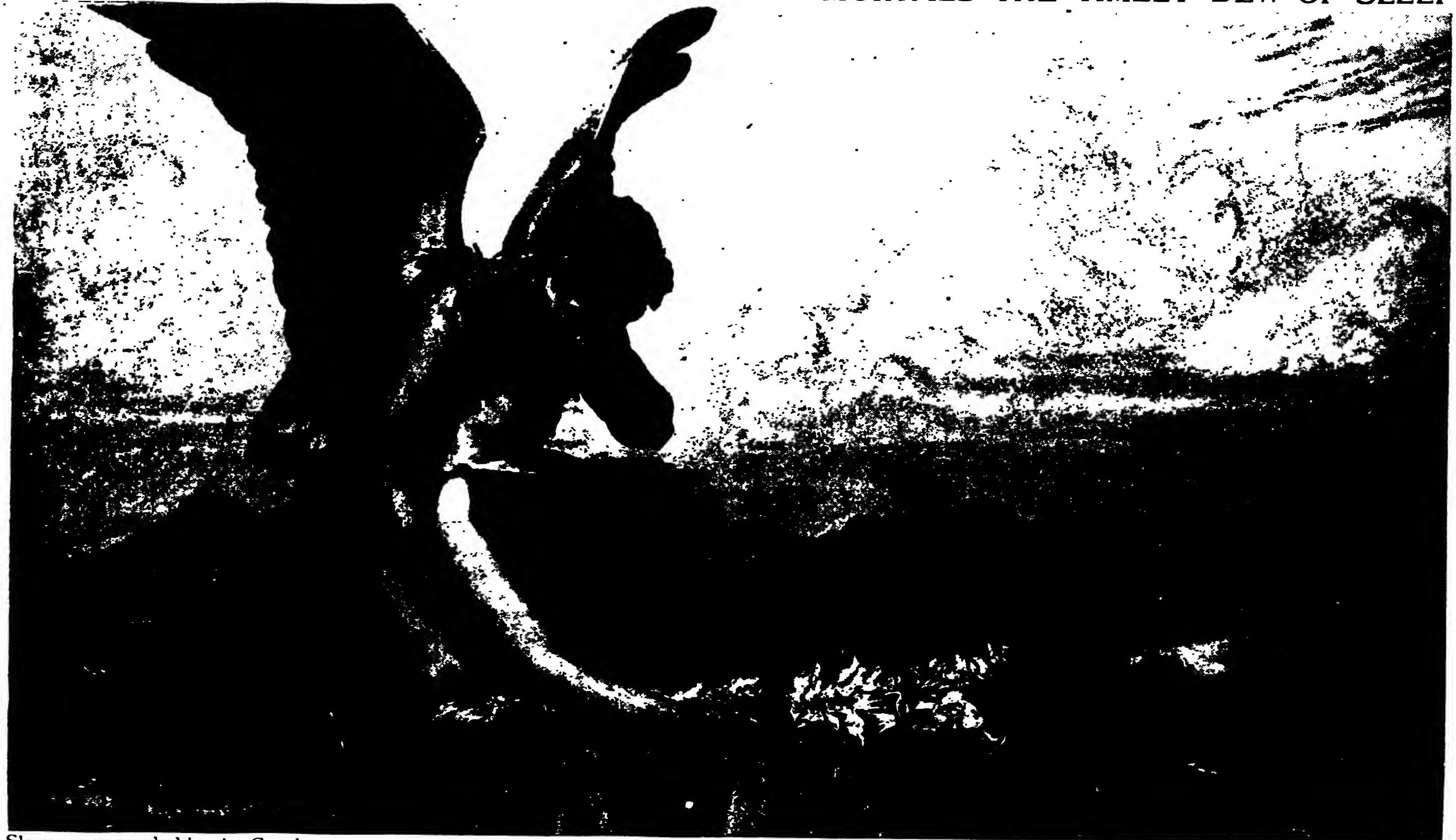
The one Sugar and the Many Inorganic Salts that are in the Blood

Other organic food-substances must be noted, the chief of these being the special form of sugar called glucose. No other sugar can exist in the blood; and all other sugars we consume, whether in milk, or fruit, or sweets, together with all the starch in the food, are converted into glucose and circulate as such in the blood.

The inorganic salts of the blood are very numerous. The metals represented are chiefly sodium, potassium, calcium, magnesium; and these form various salts, especially chlorides and phosphates and carbonates. The blood also contains waste-products such as urea, and a sodium salt of uric acid, on their way to be got rid of by the kidneys, with more or less success.

In all but a few details, the foregoing is no more than a mere outline of the elementary facts and principles of the new science of hæmatology, or the study of the blood. Many illustrious men of science are now devoting their whole lives to it, for it holds the key to half the problems of individual difference, of immunity from, recovery from, and susceptibility to disease, of efficiency, happiness, longevity. It is not the life, but it is the key to the life. Verily just is the universal instinct of man which reckons the first of all crimes to be the "shedding of blood."

THE KINDLY MORPHEUS WHO BRINGS TO TIRED MORTALS THE TIMELY DEW OF SLEEP



Sleep was regarded by the Greeks as so great a mystery that they imagined it as under a presiding deity whose messenger was M[illegible] is [illegible] in the above picture by W. R[illegible] [illegible]

HOW AND WHEN TO SLEEP

Sleep, Its Measurement, Length, Depth, Natural Production, Daily Rhythm, Disuse, and Wooing

THE MODERN NEED FOR A SLEEP SOCIETY

We are somewhat in danger of forgetting how to sleep nowadays. Almost every other aspect of personal hygiene has its students and enthusiasts. Societies are formed to advocate this and that; and endless controversies, which interest us all, rage about large and small matters of exercise, clothing and, above all, the minutest and most trivial details of diet. But there is no Sound-Sleep Society—though many societies, otherwise named, illustrate that ideal—and no one who is not an expert realises the importance of this subject, alike for the adult, for the elderly, and for childhood. The modern world is forgetting how to rest and how to sleep.

This is the obvious and familiar remark as regards the bustle and speed of our lives. People agree that there is something wrong, and deplore the prevalence of nervousness, nerve-exhaustion or neurasthenia, hysteria, and actual insanity. But for some reason or other they do not realise that our business is to study and appreciate the practice of leisure, rest, recreation, and, above all, the due cult of. "Nature's sweet restorer, balmy sleep." The hackneyed words are too familiar, like many greater words still, to impress us as they should. We all want restoring, at times; and we take tonics and stimulants and exercises, and change our diet on broad or narrow lines, or seek change of air, and so forth, and neglect the "sweet restorer" with which nothing else can compare.

It is quite possible to agree with King George when he said, "Wake up, England!" and to argue that much national danger and much personal ill-health are due to lack of action, and yet to preach this gospel of sleep. The gospel of work is a good and necessary one, and will certainly be preached here, for no modern student of hygiene, knowing that inactivity is the road to death of any function or organ of any living being, can ignore it, but the whole point of the present argument is that good work and good sleep promote and are the conditions of each other. Both are characteristic of health, and there can be no real health without them. Only the man who sleeps well wakes well, and only the man who wakes well sleeps well.

The distinction between what we call sleep and what we call waking is only relative. There is a continuous gradation, in reality, from abnormal and, so to say, morbid sleep at one end, through many stages that are normal, up to abnormal and morbid excitement at the other end. At the lower extreme, not far short of death, is the deep unconsciousness produced by narcotic drugs in sufficient dose, by morphia, chloroform, alcohol, ether, etc., in apoplexy, coma, and also in the curious condition called catalepsy. Higher up the scale we come to the very deep sleep which betokens exhaustion or long lack of sleep, but which appears to be normal and customary in some people. Then come the various levels of good, sound sleep, one of the most precious of possessions, and the certain condition of many more. The characteristic of this kind of sleep is that it is dreamless, as we hinted in our description of the healthy man. Perhaps no sleep is really dreamless; indeed, many psychologists say so. But when we use the word we usually mean that there is no recollection of any dreams, and in that sense good sleep is dreamless. No doubt there are many people who seldom or never attain this kind of sleep. They are never quite asleep, and very likely they are never quite awake. It would probably be worth their while to try to improve the quality of their sleep, though the modern hygienist is bound to

admit the natural variability of mankind, in this as in all other respects, and to qualify the expectations of those who think that anything is possible to determination and patience.

Somewhat higher up the scale come the light kinds of sleep, of the "forty winks" pattern, when we dream a good deal, even imagine and invent and anticipate and remember a good deal, partly know where we are, and are apt to deny that we have been to sleep at all. From such sleep we are, of course, very easily roused; and some people seem never to get much more than this kind of "cat-sleep," as it is sometimes called. But though the amount of noise required to wake a given sleeper is usually a good and trustworthy index of the depth of his sleep, and has been experimentally used to study the depth of sleep from hour to hour, we must remember that people's ears vary widely in sensibility; and some who have good, sound sleep may be very easily wakened, and may wake wholly and quickly in a second.

The Power of Paying Attention Regarded as a Measure of Sleepiness

At this point the stages crowd upon one another, and may be missed, like the stages between the liquid and the gaseous state of water, but they are there, nevertheless. Anyone who has listened to a dull lecture or read a sleepy article—*absit omen!*—knows how attention flags and returns; we are in the intermediate stages. Those who have observed themselves may have noticed, also, how on going to sleep the train of thought is occasionally lost, and one cannot regain it, as if a thread or two of the texture had dropped below the level of consciousness, while most still remain before submergence. Other people, no doubt, go to sleep quickly and all-of-a-piece, just as many people wake. If we think further, we shall see that the stages of waking or wakefulness are many. There is lazy attention or half-attention, as of the old man who, speaking the honest truth for most of us, said: "Sometimes I sits and thinks, and sometimes I just sits." He was sometimes awake enough to think, and sometimes only awake enough to sit. We must sharply distinguish between this state and that of genuine absent-mindedness, or absorption, which may be intensely wakeful, but asleep to present surroundings. The two states may be judged identical by other people, but are profoundly opposite. Next there comes the ordinary waking state when we are all there, and attend duly, without being incapable of having our attention diverted. Beyond this there are many stages of excited and tense attention, as of the soldier who is so awake to the fight that he is unconscious to the bullet in his leg, leading up to the intense and passionate and dangerous absorption of ecstasy, usually religious in form, or of agonised and sleepless grief.

Is It Possible to Measure Truly the Amount of Our Effective Sleep?

The table of stages is a long one, but it is worth reviewing, because no one who has not the idea of it in his mind is really prepared to understand anything about sleep, and also because such considerations as these help us if we are inclined to make any intelligent study of the most interesting and available thing in the world, which is our own minds and their processes.

If sleep has all these variations in depth, how are we to measure them? The measurement must be made, for practical purposes, and certain means are available. It will no longer do to assume that the quantity of sleep can be measured by the clock. That is no more possible than it really is possible to measure a man's age, as if he were a tree, by the number of our planet's revolutions round the sun. The clock can only measure the length of sleep, but the length of sleep is of comparatively small importance compared with its depth, which the clock cannot measure. No one's life or health or sanity or efficiency can do without a certain minimum of sleep; and it is a mistake to assume that, if one man gets five hours and another ten, the first needs only half as much sleep as the second. If his sleep be twice as deep, he gets as much, but he gets it quickly. This a very precious faculty for the worker; and if it can be learnt, which may in some degree be possible, the learning is worth while.

The Best Test of How We Sleep to Be Found in the Feeling of Refreshment

One hour of sleep of the best quality is worth many hours of the worst. Indeed, most of us have had the experience of a kind of partial sleep which exhausts instead of refreshing us. We should have done better not to have slept at all in that fashion, but to have spent the time in placid, easy wakefulness, as many wise old people learn to do when they cannot sleep. On all these grounds the measurement of the depth of sleep is worth undertaking, not least because we require to learn, with our modern habits, whether it is really true that an hour before midnight

is worth two afterwards, and whether that early sleep is really entitled to be called one's " beauty sleep," as the phrase goes.

The depth of sleep may be measured by its results, as doctors and nurses soon learn to do. They observe the degree to which the patient is recuperated, and they know how deeply he must have slept.

Secondly, the depth of sleep can be tested by experimental stimulation of the sleeper. Such students as the Indian thieves who will steal a blanket from under a sleeping man without waking him make experiments of their own. More academic physiologists can employ any graded stimulus of touch or sound, and observe at what stages the greater stimulus is necessary to wake the sleeper. The results are definite and interesting. They do not justify the assertion about sleep before and after midnight, but they explain it, as also the phrase about " beauty sleep." They show that six hours of sleep are by no means equal to twice the first three, for we sleep deepest at the beginning—not of the night, but of our sleep, whenever that may be. It matters nothing, in itself, when one sleeps, though natural light is better than artificial light to live and work by, and our sleeping habits may tell in that way. But so far as the sleep itself is concerned, we sleep deepest in the first few hours; and then our sleep gradually becomes shallower and shallower, until we waken—spontaneously, as we really should do, because consciousness has reached the surface again, in the convenient metaphor which psychologists can scarcely avoid the use of.

How Far May Dreams Be a Guide to the Quality of Our Sleep?

Thirdly, the depth of sleep can be measured, as we have already hinted, by the dreams. This, indeed, is where the study of dreams finds its value to-day, and this is where they may indeed be held capable of predicting the future—for the man who habitually has coherent and well-remembered dreams, especially if they be repeated, may look upon them as rather ominous, whatever they may be about. He is probably not getting a good quality of sleep, and should see to it. Best of all is to have no dreams; or, if we all must dream, to have no remembered dreams. Next best is to have one's dreams few, undistressing, and so incoherent that they can scarcely be pieced together afterwards. Definite, clearly articulated dreams, which we can recall in detail, are less satisfactory, for it seems probable that they involve the action of more areas of the brain, and thus mean that more of it was awake at the time. Worst of all are nightmares, which are a real evil, definitely condemnatory of the quality of sleep, and demanding serious attention. Nightmares are frequent in one particular form of heart disease, which is not common, and is becoming even less so. As a rule, the disturbance which so uncomfortably excites, and half awakens, the brain, in these cases, is to be found in the stomach or some other part of the digestive tract, and dietary errors are to blame.

The Parts of Us that "Go Easy" but Never Sleep While We Rest.

And now let us see what sleep consists in, and what are the characteristics for health of this state. This inquiry is part of physiology, strictly speaking, but it is so close to hygiene that we must treat it here.

No one knows what happens when we sleep. To understand sleep entirely would be to understand waking, to know what mind and consciousness are. But some things we do know. The whole nervous system cannot afford to sleep. Breathing must continue, and the control of the heart, each of which involves the sleepless activity of certain nerve-cells. The heart itself cannot sleep, but must content itself with the rest it gets between its beats. Nevertheless, everything " goes easy " during sleep, as far as possible. The muscles are relaxed, losing their " tone " and so getting rest. This cannot apply to the breathing muscles, but breathing is somewhat slowed, as the bodily work is now reduced to that of the heart and the breathing muscles themselves, so that comparatively little oxygen is needed, and comparatively little carbonic acid is produced. The nerves governing the size of the blood vessels relax their orders, and the vessels on the surface of the body are seen to dilate. The kidneys do exceedingly little work during sleep; and if there is marked evidence to the contrary, disorder of the kidneys may reasonably be expected.

The Need for Refreshing in Sleep the Ceaselessly Active Nerve-Cells

As we have seen, even the middle areas of the nervous system may not sleep entirely during what we call sleep, but the uppermost centres—those which are concerned with the waking consciousness and the expression of the Self—these do indeed sleep, after their unbroken and wonderful activity of so many hours in succession. We should remember that a period of waking, say, of sixteen hours, means the ceaseless and watchful functioning of millions of

nerve-cells; and the real marvel is the machinery of nutrition and of drainage of waste products whereby these cells can be kept going without a moment's intermission for so long a period. Further, we are to note that sound sleep means the relaxation of all emotion, which is a very costly business, involving great nervous wear and tear. So much the less satisfactory is that sort of sleep which includes nightmares and other dreams, with their emotional cost.

The Increased Need for Sleep in the Young who are Growing and the Old who are Resting

In the case of the child we further find that sleep is the period of growth and development. Those processes are retarded where children's hours of sleep are too short, or where they live in too much noise—a matter of national moment, and profoundly affecting those children's personal health in later years, including, probably, their capacity to sleep soundly. There is reason also to suppose that sleep is no less important at the other end of life. We commonly say that the old need less sleep, which appears at first sight to be true. But it may often be that they cannot get more sleep, for they are losing the capacity for sleep, and that they grow the older in consequence of the loss of this great restorer. Those who have care of old persons whom they love should try to promote their sleep, persuade them, like young children, to sleep after the midday meal, and so to prolong their years, as there is every reason to expect.

Sleep is above all sleep of the brain—more so than of the rest of the body. It is therefore closely related to disease of the brain; and lack of sleep should above all be attended to in persons whose nervous systems are unstable and who have a liability to insanity.

Sleep More Nourishing Even Than Food—"Who Sleeps, Dines"

When the whole evidence is summed up in this fashion, and when it is added to the vastly more weighty evidence of daily and nightly experience, we may begin to appreciate the profound justice of the words which Shakespeare put into Macbeth's mouth, when he calls sleep "chief nourisher at Life's feast." The French express the same idea, less forcibly, but very tersely, when they say: "Qui dort dîne"—"Who sleeps, dines." The truth is that he who sleeps does much more than he who dines. Sleep is not only the equivalent of food—it is "*chief* nourisher at Life's feast." The evidence of illness proves this at once. Here we find that the patient must sleep. Food is an entirely subordinate matter. Probably the patient cannot digest. In any case, the body has reserves of nourishment, if only it can cope with the poisons that threaten it. Sleep will save it, economising its profoundest forces, and enabling it to avail itself of its innermost resources. The skilful doctor knows that food will probably not be digested, and, in consequence, will interfere with sleep—which is precisely the last way in which to keep the patient's strength up. On the other hand, he knows that the right kind of nurse or friend, who will not worry about food, but whose influence is soothing and may induce sleep, may well mean the difference between life and death to his patient.

The Unexplained Mysteries of Sleep, Physical, Chemical, and Hypnotic

What happens in the brain to produce sleep we cannot say. Physical or chemical changes, or both, must occur; and the problem is not entirely unpractical, for the solution of it should help us to control sleep and produce it safely. It is well known that the cells of the brain have a large number of short branching processes, radiating from them, which are called dendrites. These dendrites, unlike the long processes of nerve-cells, appear not to communicate with other cells so much as to nourish, in some way, the cell to which they belong. They are observed to be damaged in certain chronic degenerations of the brain-cells, such as are observed in alcoholic insanity. It is also asserted that, during sleep, these dendrites are withdrawn, or partly withdrawn, into the cell to which they belong, so that we may suppose it to be deprived, for the time, of its "feeders." Another theory of sleep is chemical, and leads to notable conclusions.

According to this view, which cannot but be part of the truth, though it is doubtless not the whole, waking and sleeping depend upon a chemical rhythm within the body. While we are awake we gradually produce and accumulate a certain substance or substances, which we may call the natural hypnotic. The store of this substance in the body slowly mounts up, its quantity being largely dependent, normally, upon the degree of our activity, whether mental or physical. At the end of the day the quantity becomes such that we feel ready for sleep; and in favourable

conditions of quiet and darkness—such as every hypnotic is entitled to—we sleep. Let us observe, now, how this theory tallies with the diurnal rhythm of the normal man.

When the dose of this natural hypnotic has mounted high enough, he sleeps well and deeply. Gradually it begins to diminish in abundance, no more being now made, and the intensity of his sleep is reduced, as we have already seen. Meanwhile, no doubt, his brain-cells are also accumulating food-material, of which they have been partially exhausted; and now the man wakes. But if we observe him closely we find that he is not yet at his most wakeful. Even after obvious waking most of us require a few hours before we become as awake as we may be. Most people are not at the " top of their form " in the early morning; it is in the early afternoon, normally, that we appear to become most fully awake, and then, after a time, slowly sleepy again.

The Time-Table of the Body, Bringing Us Into a State of Rhythmical Rest

There is thus a daily rhythm which, though it appears to consist of two abruptly marked phases, is really continuous, but how smooth and continuous we can scarcely guess unless we adopt the practice of going to bed when we feel sleepy, and allowing ourselves to waken spontaneously.

The recurrence of this rhythm, it is here suggested, may well correspond to the chemical theory of sleep. We awaken when our natural hypnotic diminishes in quantity, though we do not fully waken until it has diminished further; and then our full waking begins to increase its quantity again. The evidence as to the rhythm in the waking hours is partly derived from the experience of people who have to write and lecture. It is familiar to singers that they cannot nearly do themselves justice in the morning—not until their voices have got warm, as they put it. And it is the fact that the various athletic records are made in the afternoon. A sprinter is perhaps a couple of yards faster, as the phrase goes, at 2.30 p.m. than he was at 9.30 a.m. His nervous system is now completely awake, and everything is capable of going at its smoothest and quickest.

No brief assertion, however, will encompass the facts of anything so complicated as sleep. There can be no doubt that the quantity of blood in the brain is one of the factors of sleep. The late Professor Angelo Mosso, of Turin, most celebrated as a student of fatigue, made many experiments with a table so exquisitely balanced that it would lie horizontal with a man upon it, but respond to any change in the distribution of his weight. He found that, when such a man was asked to do a sum, the end of the table where his head was at once began to sink, because of the increased quantity of blood which flows to the brain, as to any other organ, when it is being called upon for active work.

The Problem of the Amount of Blood in the Brain in Relation to Sleep

Such observations, and many others, lead us to suppose that the quantity of blood in the sleeping brain must be diminished. They help us to understand why one should be warm enough in bed, meaning that we have plenty of blood in the skin; they partly explain the serious objection to cold feet in bed, and the fact that toasting the toes at the fire after a hearty lunch, and thus liberally supplying the feet and the digestive system with blood, may markedly promote sleep, notwithstanding what we have said about the natural rhythm of sleep and waking.

Even so, we must not overstate the facts. The evidence suggests that a *too* bloodless or anæmic brain cannot sleep. In very many cases of sleeplessness, especially among the elderly, whose arteries are beginning to stiffen and cannot relax as they should, doctors believe that this is the cause, and they employ warm drinks at night, and other means of relaxing the arteries in the brain, and often thus succeed in producing sleep. Thus the sleeping brain appears to be one in which there is definitely less blood than in the alert and waking brain, as we should expect, but it is not a brain emptied of blood.

The Activity of the Body as One of the Most Natural Inducements to Sleep

All the foregoing facts consort with the view that activity modifies the composition of the blood, and is associated with the production of something which, in suitable dosage, promotes sleep. Busy days make balmy nights; and the business may be of mind or of body. One of the facts discovered by Mosso was that physical exercise produces certain chemical compounds which lower the activity of the whole body. We may say, from one point of view, that they produce fatigue, and from another that they are natural sedatives. It is not merely the muscles involved in the exercise that are involved in its

results. Violent and prolonged exercise of the legs tires the arms (though in much less degree), and *vice versâ*, for the fatigue-products are carried by the blood to all parts of the body. They are carried to the brain, and, on the one hand, help it to sleep, and, on the other, interfere with its working power. It is profoundly true, in some ways, that a change of occupation is rest, but it is a delusion in another way.

We Must Work Hard in Order to Sleep Better, Deeper, and More Dreamlessly

We have done our boys and girls much harm, in the last few decades, by assuming the entire truth of this doctrine. Only too often we have set them to games and physical exercises, and then have expected good brain-work from them, not knowing that we have altered the composition of the blood in a manner which " rests " the brain only in the sense that it predisposes the brain to rest and interferes with its activity.

Work, then, under certain conditions afterwards to be defined, would appear to be the best hypnotic—probably because it involves the production of the natural hypnotic. That is the chief contrast between work and worry, and the chief condemnation of the undiscernment which attributes to one the effects of the other—as we shall see when we come to study worry, that arch-enemy of health. Work promotes sleep; work harder, and you sleep better, sleep deeper, and dream less—which is the sure sign of improving sleep. Work harder still, and you fall asleep at your work—admirable and protective arrangement. But when we say work we mean work and nothing but work—pure, uncomplicated activity of any order. Introduce but a tincture of worry into the work, or omit the work altogether, leaving worry, and sleep vanishes.

Hard Work Should Be Harmoniously Balanced by Deep Sleep

There is a definite relation between work and the need for sleep—and its quality. The hard worker should be a proportionately deep sleeper. The idea that only the brain is refreshed by sleep, or that only brain-work requires sleep, is absurd. Sleep is much older than the modern brain. Hard muscular work involves the need of sleep, even though sleep be, above all, rest of the highest areas of the brain—which are not involved, we might suppose, in muscular work. But muscles are only driven by the orders of nerve-cells; and much of what we call muscular fatigue, because it shows itself in the muscles, is really nerve-cell fatigue or exhaustion, not to mention that the by-products of muscular action reach the nervous system and affect it. The brain works, in its way, when muscles work, and the physical worker requires due rest. Fortunately, he gets it. Only the happy child gets the constant quality of unfailing sleep which is the blessed portion of the man who works all day in the fields, and who has no nervous distress or worry to complicate the naturally hypnotic quality of his work.

Most of us are brain-workers nowadays, and have to face a novel problem. It is an instance of what Professor Metchnikoff calls the " disharmonies " of our constitution. The contrast between the difficulty with which, too often, the brain-worker obtains sleep, and the case of the manual worker, suffices to show that man, as at present constituted, is better adapted for physical than for mental work. This " disharmony," like many others, is due to our amazing development of brain—while the body and its needs persist. Given that one has to have a body, there is a danger in habitually sedentary mental labour, a danger which most of us must avoid by a little personal wisdom. We must take our daily exercise as well as our daily bread—probably a little more of the one and a little less of the other.

The Difficulty When the Nerve-Machinery Runs on Beyond Its Time and Will Not Rest

Further, we must note that, just as the nervous machine requires some time for warming up in the morning, so it is very apt to go on working when its activity is no longer desired.

At both ends of the day one should recognise the indications of the natural rhythm, as indeed most of us do. To read the paper and to answer one's letters is less hard work than to originate, invent, advance—which we keep until the other is done. And at night, though the quiet and the security from interruption offer many temptations to the brain-worker, we should gradually relax our ardour. If we are going to spend an hour or two on really hard work, such as study of any kind, it should not be the last at night. We shall get better results from the same time when the brain is fresher and attention is easier. Let the last hours be easily spent, especially if getting to sleep is a problem.

If we appreciate the physiology of sleep, as regards the relative distribution of blood to the skin and the brain, and also as regards the more lazy breathing, we shall see that people who suddenly make the change from

a stuffy bedroom to a properly ventilated one may find that they cannot sleep. Carbonic acid gas, which we expire when we breathe, is the natural narcotic, and does its blessed work in soothing almost every death-bed, all the fictions about the "death-agony" notwithstanding. Thus, if we go to bed in an unventilated room, where it is easy to be warm, and where the proportion of carbonic acid in the air soon rises, we shall find it easier to sleep than at first, when we take to purer and cleaner conditions. Doubtless, also, the transition from a feather bed to a spring mattress seems less comfortable and sleep-inducing at first, though the feather bed seriously interferes with personal ventilation, and should disappear from all modern households.

Some Practical Hints About the Sleep-Inducing Arrangement of Beds

The remedy is to recognise that a sleeper is entitled to warmth. Keep the window open, sleep on a proper bed, and by all means throw on an extra blanket if it be needed—a simple remedy. And since we are so far, the question of the bed may be settled once and for all. A bed should be single; the regular practice of sleeping with a bedfellow cannot be really hygienic. The modern fashion of two little beds side by side, for husband and wife, is a great improvement. A bed should be wide enough to permit of a fair amount of movement, and need be no wider. Let the clothes be wide, and cold need not be feared. There should always be a blanket between the under-sheet and the mattress. Dark coverings, of the rug pattern, are to be questioned, like anything else that "keeps clean a long time" or "doesn't show the dirt." Dirt is just as much dirt whether obvious or concealed. Many cleanly people are astonishingly unparticular about their beds, and less cleanly people are deplorable. One's bed is very personal—as personal as one's underclothing, and scarcely less exposed to the products of one's person. Probably, also, many varieties of infection, such as that of a common cold, to name nothing more serious, are retained by the outer coverings of a bed, to do damage on future occasions.

The Abuse of Growing Life in Not Allowing Children a Sufficiency of Sleep

Of course, a bed should have no canopies, curtains, or any of the other devices with which our forefathers suffocated and devitalised themselves, and stored infection. If any critic should suggest that our ancestors' practices, here or elsewhere condemned, "did them no harm," he evidently has the onus of explaining why their death-rate was so much higher than ours.

But before we proceed to study in detail the problem of obtaining sleep and recovering it, in health and in disease, let us completely satisfy ourselves that this is a greatly neglected problem of the first importance. Above all does it matter for the nation's childhood. We are all wrong in this respect; it is not a problem of poverty only. Several of the most distinguished doctors in this country lately addressed an important letter to the "Times," in which they showed that our public schoolboys do not get nearly enough sleep. In America this absurd abuse of growing life, where no excuse exists for it, does not obtain. Some improvement has already been made at Eton and elsewhere, notably in the abolition of early morning "prep," an imbecile custom whereby boys were roused out of bed and set to difficult work before breakfast. Needless to say, they learnt nothing under such conditions; and the whole thing dates from the period when education was thought to consist, above all, in denying the natural needs of childhood and youth. Until three or four years ago, the average amount of bedtime allowed in our public schools was from eight to eight and a half hours, not all of which were necessarily spent in sleep.

The Need for Providing the Nation's Children with an Adequate Supply of Vital Sleep

Such a period is wholly insufficient for the growing boy or girl of any race or class; and its maintenance in our great and wealthy schools in the present century is only one instance of the national indifference to the teachings of science, such as neither Germany nor the United States of America can be accused of.

As for the "half-timer" in the North, awakened by the "knocker-up" between 4.45 and 5.30 a.m., that is an abomination which is about to cease. But it will be many a long day yet before the childhood of the nation is adequately provided for in this vital respect, wherein the teachings of modern physiology and psychology so entirely confirm and amplify the best wisdom of the past. And it may be as long before the warnings and the teachings of the hygienists instruct grown-up people as to the value of sleep, its fundamental importance for health, the right ways of attaining and maintaining it, and the wrong and deadly ways — the very urgent questions which must next claim our attention.

A BARRIER PIERCED BY THE TUNNEL MEN

A STEEL BRIDGE STRETCHING FROM TUNNEL TO TUNNEL OVER A GORGE IN THE ANDES

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PIERCING THE EARTH

How by Tunnelling Man has Made New Avenues for Traffic and Pierced Nature's Most Stupendous Obstacles

MOUNTAIN SEA AND CITY UNDERMINED

MAN, who is just beginning to conquer the air, has long since conquered the earth. He allows nothing to stand in his way. Does he wish to get to the other side of a chain of mountains? He goes the straightest way—through the heart of the mountains, boring like a worm, yet with marvellous accuracy and speed. Must a river be crossed without a bridge or a ferry? He burrows beneath the river-bed from one side to the other. Is there no room in a big city for the transport of the swarming millions of workers? He carries them far below the surface in tubes of iron, laid in burrowings, out of sight and sound of the roar of the surface traffic in the busy streets. And all this wonderful work is done out of sight of millions of his fellow-creatures, to whom the romance, the danger, the difficulties, the skill displayed, are almost unknown.

The great era of tunnelling began with the work of the early railway engineers, when a nearly level way was necessary for the running of smooth wheels on the iron track. But the work of cutting the tunnels at that period was almost beyond belief more difficult than the boring of tunnels is at the present time. Then men delved and toiled with pick and shovel in the heart of the hills by the dim gleam of candle-light, which rendered "darkness visible," with no protection overhead save that of the timbering and propping that was done as they cautiously advanced. Roofs might fall in and crush them. Springs might burst in and drown them, or foul gases poison them. Against these risks and uncertainties there was no manner of protection beyond readiness and alertness to deal with such difficulties as they arose.

That was the old style. In the modern way, the men work with comparative safety within a closed apartment of steel termed a "shield," by which they are protected from such risks, though of course some accidents do happen, but not in consequence of falls of roofs, and seldom indeed now from irruptions of water.

The oldest tunnel, perhaps, in the world was one under Monte Salviano, for the draining of Lake Fucino. It was over 3½ miles in length. The Catacombs were ancient tunnels. The longest tunnel in the world but one has also occupied the longest time in construction. This is at Schemnitz, in Hungary, constructed to carry off the water from the Schemnitz mines to the lowest part of the Gran Valley, and is 10·27 miles long. It was begun in 1782, and was not completed until 1878—96 years in the making—and it cost nearly a million sterling. It is, however, of small section, being only 9 feet 10 inches high, and 5 feet 3 inches wide. During the period before the French Revolution, the cost of cutting was £7 per yard of length; during the later period of the work it cost £22 per yard.

Tunnel-making of this kind, though tedious and dangerous, is a very different thing from tunnelling under rivers and high mountains. When long railway tunnels are bored under hills, shafts are sunk in the first place at intervals along the proposed line, and these provide the means of ventilation, as well as of alignment. This method is impossible under streams and mountains. None of these tunnels, now so numerous, could ever have been made but for the invention of the shield just mentioned. The conception of this was due to Brunel, who used it in his famous tunnel under the Thames.

Earlier in the century an abortive attempt had been made to tunnel the Thames between Rotherhithe and Limehouse. Begun in 1802 by Mr. Vazie by the sinking of a shaft, the tunnelling was commenced in 1807 by Trevithick. It never got further than 1100 feet from the shaft.

Several times the river-bed fell in and drowned the works; and then clay and gravel were dumped into the openings, and the water was pumped out. Ultimately the labour of five years was lost, and many thousands of pounds sunk in vain.

Brunel drew his idea for boring the Thames Tunnel direct from Nature. When in 1809 another proposal was made for boring under the Thames, it was, as is usual with novel schemes, pronounced impracticable by one of the greatest mathematicians, and one of the most accomplished civil engineers of the period. This view, too, seemed justified by the late disastrous experience, and so the matter remained in abeyance for several years. But in 1816 Brunel happened to observe critically a very familiar object which he would have often noticed before—just a piece of ship timber lying in Chatham Dockyard, perforated by a tiny worm. In the words of his biographer, Mr. Beamish: "He examined the perforations, and subsequently the animal. He found it armed with a pair of strong, shelly valves, which enveloped its anterior integuments, and that, with its foot as a fulcrum, a rotatory motion was given by powerful muscles to the valves, which, acting on the wood like an auger, penetrated gradually, but surely, and that as the particles were removed they were passed through a longitudinal fissure in the foot which formed a canal to the mouth, and so were engorged. To imitate the action of this animal became Brunel's study."

Brunel's Bold Pioneer Action in Making a Tunnel Under the Thames

The result was that in 1818 he took out a patent for his cellular boring-machine. In 1824 a company was formed, and a Bill passed to promote the construction of the tunnel. The work was begun in 1825, but the tunnel was not opened until 1843. Eighteen years! Other similar tunnels under the Thames, of which there are now twelve, reckoning double tubes, have been constructed in about one-fourth the time. But Brunel was the pioneer to whom belongs the honour of having made the first shield.

The shield was composed of thirty-six independent divisions or little cells, within which the men hewed away at the face of the soil, throwing it behind them whence it was carted away. A depth of three feet in front was excavated at a time in little pockets, and the shield was moved forward by means of hydraulic jacks. Then the clear opening of three feet left behind was lined with brickwork. A square passage was thus cut and lined with bricks, 37 feet 6 inches wide and 1200 feet long. Within this, two arched tunnels were built, each 14 feet wide by 17 feet high, connected with cross passages at intervals. The tunnel was driven from one end only. Nowadays the practice is to bore from each end, and meet in the centre.

Before the shield could be brought into service a great shaft of brickwork 50 feet in diameter, resting on an iron curb with a cutting edge, the whole weighing 910 tons, was sunk at Rotherhithe, and into this the shield, composed of twelve distinct frames, was lowered and placed in position; and on November 28, 1825, the miners and bricklayers began their eventful work.

The Sensational Ups and Downs of a Great Engineering Enterprise

And such a task! Week by week the story is one of incessant worry, accidents, falling in of soil, flooding, illnesses of Brunel and his assistants. A big disaster was that of an irruption of the river on May 18. The water "came on in a great wave," the lights were extinguished, and the miners barely escaped to the shaft alive. A great part of the tunnel became filled with the silt washed in. By means of a diving-bell the hole above was filled, and the water partially pumped out; an examination of the extent of the damage done to the shield was made in a boat floated in the tunnel, and the necessary repairs were carried out.

By this time, £170,000 having been expended, the funds were exhausted, the works came to a standstill, and the shield was bricked up in 1828. And thus it remained until 1834, when the Government loaned £246,000 to the company to renew the undertaking. The old shield, much damaged, was then removed, and a new one made to take its place. After many difficulties and disasters the tunnel was finally completed and opened in 1843, having cost £468,249. This tunnel is now utilised to connect the systems of the Great Eastern, South-Eastern, Metropolitan, and London and Brighton Railways.

The Revolution that has Followed with the Employment of Compressed Air

The story of the Thames Tunnel is one of the romances of engineering. Though twelve tunnels have been made since under the river, the sum total of the difficulties encountered in these do not equal the tenth part of those that were met and surmounted in Brunel's tunnel. Shields have been used in all, but not the Brunel shield. The successive accidents and failures and losses of life and long delays due to the irruption

of sand and water from the river overhead would not have happened if the employment of compressed air had been understood and adopted. But the time was not ripe for that. The real era of tunnel-making, done with certainty and safety, dates from the invention of the Greathead shield worked with compressed air. It was first used in this country on the Tower Subway in 1869. That was only about 7 feet in diameter. Its first great work was the Blackwall Tunnel, 27 feet diameter, which was opened in 1897.

Pioneer work in engineering is ever linked with the name of some individual. The name of Brunel is associated with the primitive shield, the name of Greathead with the more efficient one. Without its aid the numerous tunnels that burrow underneath the Thames, and the great network of London tubes, could not have been attempted.

In Brunel's shield the men worked in little cells, excavating the tunnel face. But each cell was a separate unit, which might be moved forward independently of the others. The Greathead shield is also divided into compartments, but excavation goes on over the whole face at once; an inrush of water is prevented by the employment of air under compression, exerting a total pressure of from 100 to 200 tons on the face of the soil—enough to keep back water and loose earth. The shield is a closed box with twelve compartments enclosing the compressed air, and fitted with air-locks, or valves, similarly to coffer-dams, by means of which the precise amount of air-pressure required can be regulated, and in which the lungs of the men become gradually accustomed to the difference between the air-pressure in the shield and that in the open, remaining for that purpose in the locks during a certain period when entering and leaving the shield.

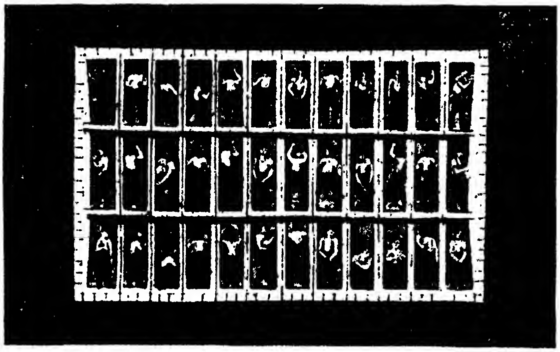
The shield may be likened to a steel coffer-dam, also having air-locks, which is sunk bodily down into a shaft, being heavily loaded, and cutting by its edges, and sinking as the central earth is excavated. The slight difference is that the shield lies horizontally, and the power to push it along is obtained from hydraulic rams, which take their support against the edges of the last iron ring which has been laid in the tunnel to form the "tube." The loose material is removed by trucks in the rear. As the shield is pushed onwards the sides of the bore are laid with liquid cement—composed of blue lias lime and sand—filled in under pressure, and an iron lining ring is built in.

A SCULPTOR'S IMAGE OF THE TUNNELLERS—"HUMAN FORCE OVERCOMING BRUTE NATURE"

Thus, however loose the soil may be, it is at once prevented from falling inwards, and the cast-iron lining, protected with a coating of concrete, is practically everlasting. It cannot rust, and nothing can crush it, being of cylindrical form, with

walls of 1½ inches or more in thickness, stiffened with flanges and ribs. It is usually lined internally neatly and smoothly with glazed bricks if for foot-passenger traffic, and in the stations, if for trains. Stiff clay will not fall inwards by tunnelling; and if pockets of loose sand or gravel are met with, the pressure of the compressed air is increased to resist and oppose its tendency to tumble in. All the expense and risk and danger to life in the timbering and underpinning method are avoided by the Greathead shield. In short, it just cuts a clean hole about three inches larger than the outside of the lining, which hole is immediately filled with an impervious armour of concrete and iron.

All shields are now built in this same general style. They are constructed of steel plates, and their diameters correspond with those of the tunnels. Thus the Blackwall Tunnel shield was 27 feet in diameter, and 19 feet 6 inches long. That in the Hudson River Tunnel was 20 feet diameter, by 10 feet 6 inches long. The power which is required to thrust them into the strata is enormous. As much as 2800 tons pressure was applied to push the Blackwall shield along, the power being supplied by twenty-eight hydraulic rams. Such rams impart the tremendous pressure of from 2 to 2½ tons for each square inch of area on their pistons. In the St. Clair Tunnel the total pressure varied from 1200 to 1900 tons. The rate of burrowing is slow, but sure, depending upon the amount excavated. In the Blackwall Tunnel the rate of progress averaged about 7 feet 6 inches during the twenty-four hours. Such work is never suspended. The men work in shifts, night and day, and on Sundays.



AT WORK IN THE THIRTY-SIX SECTIONS OF THE FIRST SHIELD USED IN THE THAMES TUNNEL

The depth at which a tunnel shall be cut is a matter of much importance. With increase in depth the difficulties of working in compressed air increase, precisely as happens with divers. A longer period has to be spent by the men in the air-locks before entering and after leaving the working chambers, in order to accustom their blood-vessels and tissues to the differences in pressure. Higher wages have to be paid, and only the soundest men can endure the physical strain. A pressure of 35 pounds per square inch above that of the atmosphere is usually sufficiently high for the deep tunnels.

On the other hand, compressed air is not used in shallow tunnels when there is no risk of the irruption of soil or water. Thus shields alone were required in driving the London tubes, excepting in some localities where they came close to the surface, as at Shepherd's Bush and Holborn Viaduct, when the compressed air was required to oppose the pressure of the loose soil.

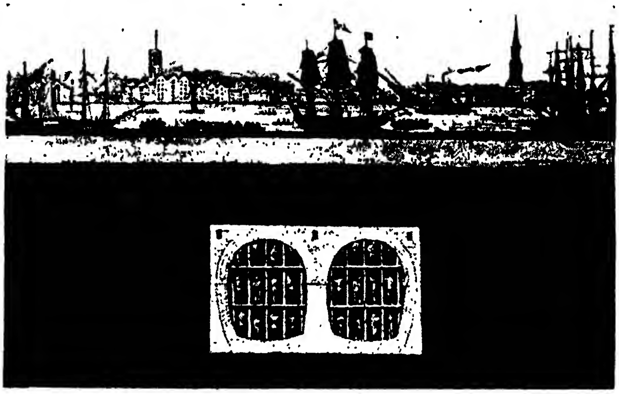
The Blackwall Tunnel is 6200 feet long between entrances, but only 3083 feet is sub-aqueous tunnel proper, bored and lined with cast-iron tubing. This was the largest which had been constructed up to that time—1892—with a shield. The difficulties were so formidable that the London County Council hesitated to sanction it, until reassured by the advice of Sir Benjamin Baker and Mr. Greathead. Messrs. S. Pearson & Son, who took the contract for £871,000, were advised by friends to leave it alone. But the firm had gained much experience in the Hudson River East Tunnel at New York, and their engineer, Mr. E. W. Moir, was instructed to design the necessary appliances, regardless of expense. The task which looked so formidable was accomplished, and a tunnel 30 feet in diameter and 27 feet inside the lining was driven through loose gravel saturated with water and within only five feet of the river-bed.

We may think lightly of men working in security behind a protective shield. It may not be a specially difficult task to push the shield along with the powerful rams after the men have cut away the soil from the front. But it has first to be got into place—a mass of some 230 tons. You cannot tumble a piece of engineering work like that 50 or 60 feet down to the bottom of a shaft to the opening of the tunnel heading. In the Blackwall shield the contractors, Messrs. Pearson, excavated a dry dock adjacent to the head of the shaft, and built up the shield in the dock. Then the ends were closed with timber, so that it would float, and the water was admitted into the shaft, filling it

up and also the dock. In this way the shield was floated out into the head of the drowned shaft. Then the water was pumped out, the shield sinking until it reached the end of the heading, where it was adjusted and directed towards its work.

The list of materials swallowed up in the Rotherhithe Tunnel will give some idea of the vast quantities involved in such enterprises: 250,000 tons of earth and stone were excavated and removed, then 27,000 tons of iron were required (chiefly for lining), 3000 tons of steel-work, 1000 tons of bolts, nearly 5,000,000 bricks, 30,000 tons of cement, 30,000 square yards of glazed tiling, 40,000 square yards of asphalt, 100,000 cubic yards of cement concrete, and 6000 tons of lime.

The quantities of materials which were used in some of our English railway tunnels may be compared. They are certainly startling: 30,000,000 bricks were used for lining the Box Tunnel, 3200 yards in length. The work occupied about 2½ years, during which period over 1000 men and 250 horses were employed. A ton of gunpowder and a ton of candles—these items appear odd now—were used up weekly.



AN OLD DRAWING OF THE THAMES TUNNEL IN COURSE OF CONSTRUCTION

How many Londoners who crowd the trains on the Inner Circle Metropolitan system give a passing thought to the vast labours of the engineers, Sir Thomas Fowler and Sir Benjamin Baker, names comparatively little known then, who constructed it? The story of that thirteen miles of line, completed in 1884, is a marvel of engineering. It was far more difficult of excavation than tunnelling through virgin mountains, and vastly more costly. True, there was no danger of inrush of water, but many sewers, and water and gas mains, had to be dodged or diverted. At Broad Sanctuary 2000 feet of gas-mains had to be diverted; at High Street, Kensington, 600 feet of gas and water pipes had to be negotiated. Old houses, too, were a constant source of anxiety. Many of these had to be under-pinned with concrete, lest subsidences and cracking walls should result in lawsuits. Some of the work in the open streets was what is termed "cut-and-cover"—that is, trenches were cut, lined with bricks, and arched over. But elsewhere three separate tunnels were driven. The rail level in Edgware Road is only 9 feet below the surface; at Westminster it lies 65 feet below. The cost of this work was enormous, running into several millions, inclusive of compensations.

The deep-tunnel railways of the metropolis have solved a problem that greatly exercised the minds of Londoners previous to 1890. The old Inner Circle Underground, constructed at enormous cost, was extremely uncomfortable for travellers. Years later, when the growing congestion of London passenger traffic put the engineers upon their mettle, the Greathead method of tunnelling was adopted. In 1886 the City and South London subway was begun. Between October, 1886 and June, 1887 two tunnels had been bored under the Thames, to the intense astonishment of many who were sceptical as to the successful issue, and in 1890 the line was opened. Then followed the tunnel boom.

The tubes lie deep down in the virgin London clay, thirty or forty feet below the foundations of the houses; and hardly any of the difficulties of the old Underground built in the sixties were encountered. There were no disturbances of the ground, no expenses for demolition of buildings, or readjustments of sewers and gas and water pipes, since the tunnels all lie below them. This entails the use of station lifts, but the cost of these and their working is hardly anything by comparison with the capital outlay saved by burrowing clear of all foundations. Moreover, there is no smoke emitted, since electricity is used for driving the trains; and they fit the tubes so closely that they act as pistons in inducing strong currents of air in the wells of the lifts, which assist in the ventilation.

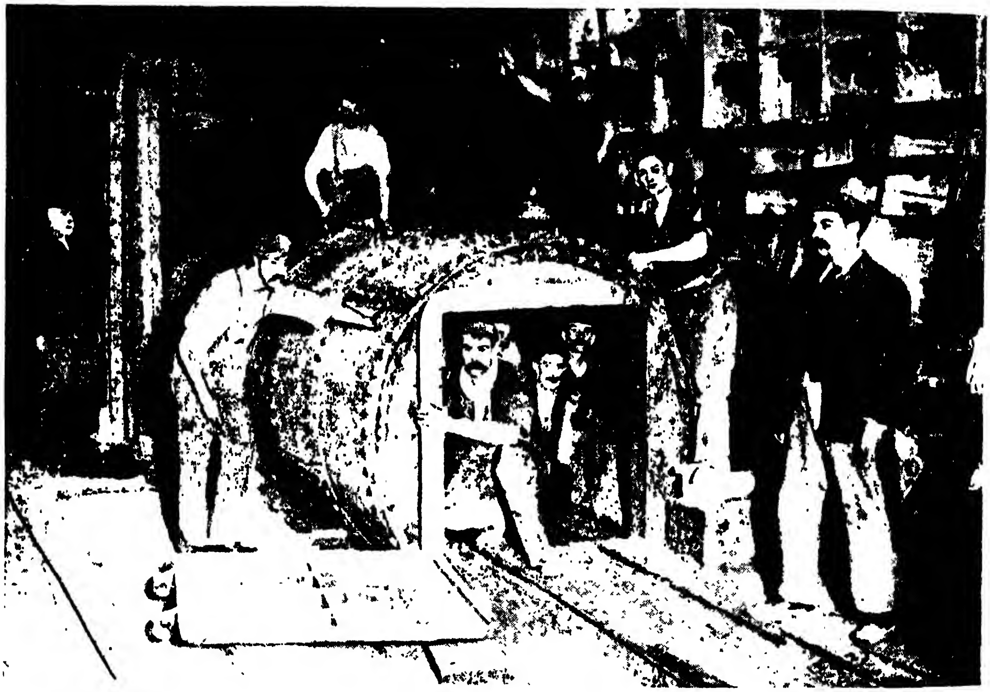
In the work of making the Central London Railway the shafts were sunk first which gave access to the stations, and afterwards the tunnel headings were driven. At each

station there are two shafts, one of 23 feet diameter, and one of 18 feet. The level of the rails lies from 80 to 90 feet down. The shafts are lined with rings of cast iron made in pieces and sunk by loading. Two sizes of shields were used, one of 22 feet 10 inches diameter for the portions of the tunnels at the stations, and one of 12 feet 8 inches for the tunnelling of the line between the stations. Messrs. Walter Scott & Middleton were the contractors, and Messrs. Mott & Hay the company's engineers.

It was on this tube railway that the first successful attempt was made to substitute an excavating machine for the picks of the labourers. It consisted of a carriage supporting driving machinery by which steel buckets or scoops, about thirty in number, attached to an endless chain, were driven, running out beyond the face of the shield into the soil. The buckets cut their way in moving forward, and threw the earth back between the carriage on their return. The machine was driven by electricity. The London subways pierce loose, soft material as well as clay. Instead of removing these by pick and shovel, Mr Greathead washed them away more rapidly with jets of water pumped out under pressure against the loose mud or sand.

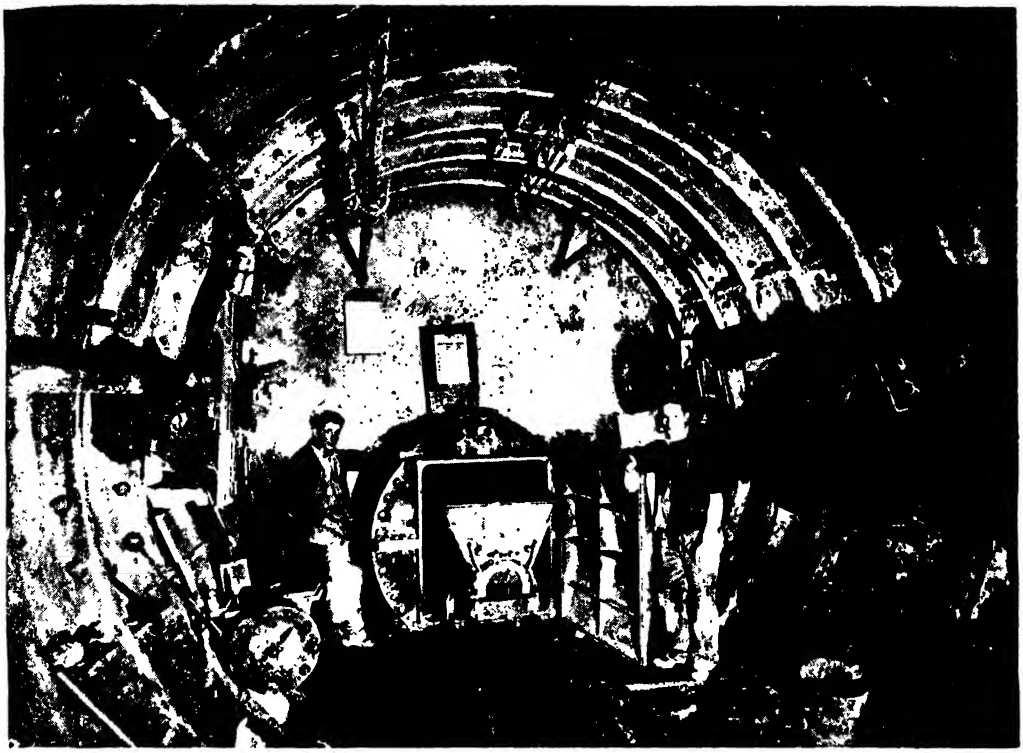
At some future time the Channel Tunnel, long since begun, may be completed. There are no engineering difficulties in the way such as those which confronted Brunel. The shield, compressed air, and ventilating fans will render it a very straightforward piece of work.

A double tunnel 2½ miles in length, of which 2625 feet is sub-aqueous, and which joins Detroit, in Michigan, with Windsor, in Ontario, Canada, under the Detroit River, is unlike any of those which we have described. The steel tubes of which it is composed were built up on land, floated out, and sunk into a trench excavated in the bed of the stream, which was of stiff blue clay. The trench was dug out with a floating dredger, and made deep enough and wide enough (48 feet) to receive the tunnel tubes, and, into the bottom, piles were driven to support them. The steel tubes were each 23 feet 4 inches in bore, their centres were set 26 feet 4 inches apart, and they were 262 feet long. A pair weigh about 600 tons. They were built at St. Clair, 24 miles distant, and brought by water to the site. The ends were secured with timber, and the tubes were launched sideways into the stream. The work of sinking them into place required great precautions. They were fitted with valves, and anchored over their destination, and



WORKMEN CONSTRUCTING AN AIR LOCK IN THE ROTHERHITHE TUNNEL

THE AIR-LOCK IN A GREAT TUNNEL



THE INTERIOR OF THE COMPRESSED AIR-LOCK, WITH TROLLEY ENTERING

THE FREE-AIR SIDE OF THE AIR-LOCK, WITH THE ENTRANCE CLOSED

THE SHIELD BY MEANS OF WHICH MAN CAN TUNNEL SAFELY THROUGH ANY SOIL

MEN AT WORK IN THE SHIELD USED IN THE CONSTRUCTION OF THE TUNNEL FOR THE GREAT NORTHERN AND CITY RAILWAY

cylinders filled with air were attached to the top. By the opening of the valves the air was allowed to escape from the tubes, and as they sank the air-cylinders gradually emptied. Divers went down and adjusted the tubes exactly, and jointed the ends with cement, while the air-cylinders rose to the surface, to be fitted to the next pair of tubes. The water was pumped out, and the interior lined with concrete and the railway tracks laid.

The most imposing triumphs of man in tunnel-boring have been won in the piercing of the Alps by four distinct tunnels, the Mont Cenis, the Arlberg, the St. Gothard, and the Simplon. The names of the mighty passes, now superseded, call up thrilling memories of campaigns, from those of Hannibal down through the long centuries to the age of Napoleon. The Alpine passes have ever been the terror of invading armies. When Napoleon said there should be no Alps, he anticipated, but in another and wholly different sense, the labours of the engineers. Within the memory of middle-aged people the tour from Switzerland to Italy could only be performed direct by crossing the Alps in the same way that the mails were carried, and which occupied from twelve to twenty-four hours. Now from a quarter of an hour to twenty minutes suffices to pass through tunnels 6000 feet below the mighty snow-clad mountains.

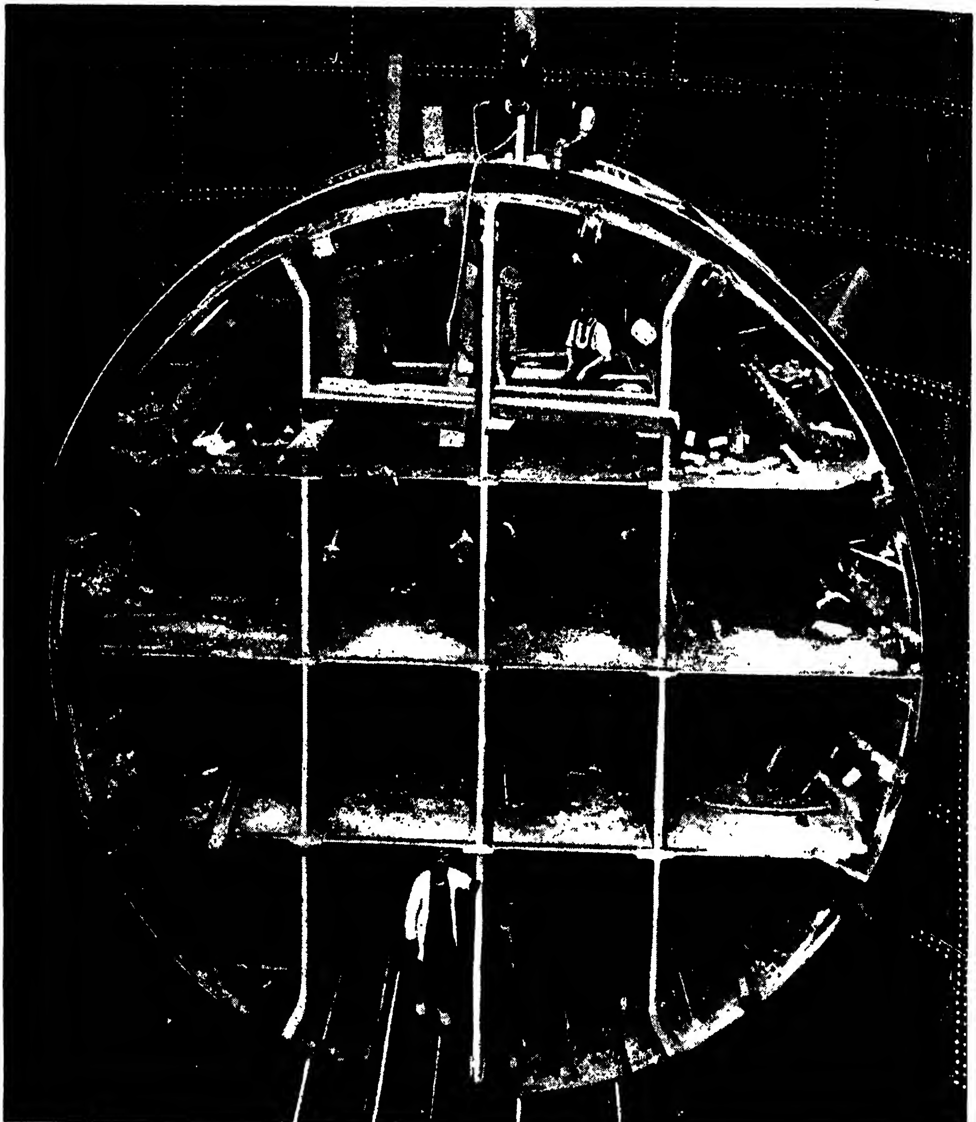
Though the tunnel shield is eminently suitable for boring in the London clay and through sand and gravel, it is of no value for dealing with rocky strata like that met with in the Alpine tunnels. These were all excavated by making a number of adjacent borings with rock-drills, and then blasting out the rock with dynamite inserted in the holes. The Mont Cenis, the first of these tunnels, was also the first in which this method was employed. The drills were driven by compressed air.

A CLOSE VIEW OF MEN AT WORK IN A SHIELD EXCAVATING THE ROTHERHITHE TUNNEL

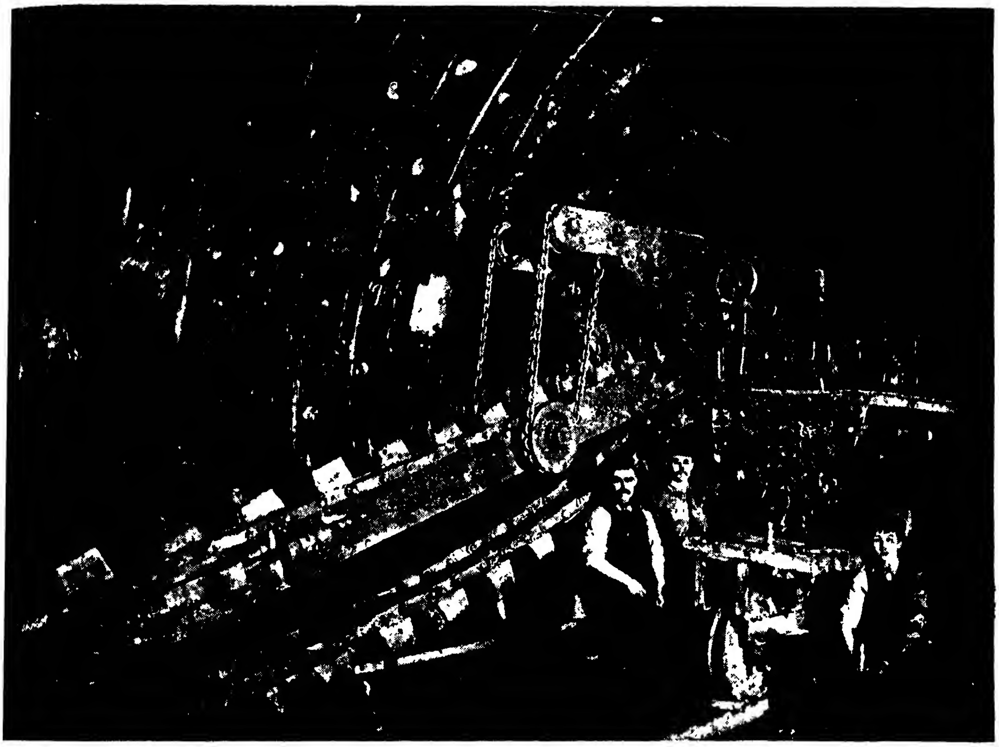
When solid rock is drilled, the whole face is not gone over at once, but a narrow channel is first cut at either the top or the bottom. This is called a "heading," after which the loosening of the remainder is a comparatively easy task. These borings through solid rock are left as borings, no linings being required as when loose earth and clay is removed.

The Mont Cenis Tunnel, the first Alpine one, was opened in 1871. It is 7½ miles

long. The St. Gothard opened in 1881, is 9¼ miles long. The Arlberg, 1883, is 6⅔ miles in length, and the Simplon Tunnel, opened in 1905, is 12¼ miles long. This last is the longest in the world, and it cost £2,350,000. But its cost per linear yard was less than half that of the Mont Cenis, constructed thirty-four years earlier. It averaged only £108 per yard, against £266 per yard for the other. Its average rate of progress per day was also greater, being as much as nine yards, while that of the Mont Cenis was only two and a half yards, and this notwithstanding that the interruptions to the progress of the work were more serious than those which occurred in the Mont Cenis. The boring of the St. Gothard occupied nine and a quarter years of continuous labour day and night, or a mile per year. It was commenced in the summer of 1872 and completed towards the end of 1881. It gave nearly continuous employment to from 3000 to 4000 men. Water-power was obtained at each end of the tunnel to drive turbines, which again actuated air-compressors. One thousand five hundred horse-power was obtained thus at the Göschenen end, and 1120 horse-power at the Airolo end. Twenty-three air-compressors were in use at each end. Locomotives driven



A VIEW OF THE SHIELD USED IN THE CONSTRUCTION OF THE ROTHERHITHE TUNNEL



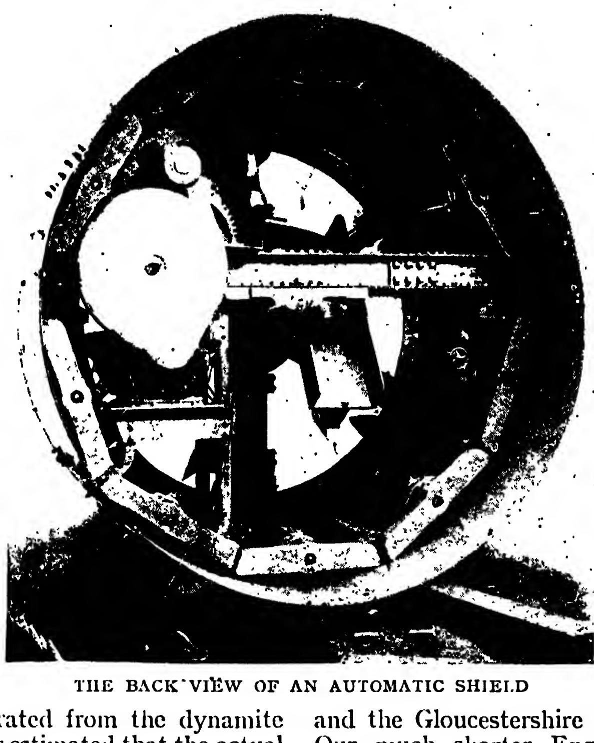
THE BUCKET EXCAVATOR THAT, WORKED BY ELECTRICITY, REPLACES HUMAN LABOUR

A CURVE IN A TUBE, SHOWING THE TAPERING OF THE STEEL RINGS

by compressed air were employed to remove the débris. This tunnel cost about £250,000 per mile, or £140 per yard.

The Arlberg tunnel through the Alps connects Innsbruck, in the Austrian Tyrol, with the Lake of Constance. It is 6⅓ miles long, and occupied three years in boring. Rock-drills were used in this work, and the cost was about £100 per yard.

The Simplon Tunnel occupied seven years in the making. It comprises two distinct tunnels, running parallel with each other, the second smaller one being for ventilation. The main tunnel is 14 feet 9 inches wide at the rail level, and 18 feet high to the keystone of the arch.


THE BACK VIEW OF AN AUTOMATIC SHIELD

Exceptional difficulties were encountered in constructing these Alpine tunnels. The temperature increases as the tunnels penetrate deeper, and as the height of the mountains increases. In the St. Gothard, just before the headings met, it was as high as 93° Fah. This caused serious delays in the progress of the work. Men were not able to do so much. The ventilation also proved insufficient, and many men and horses were suffocated by the gases generated from the dynamite in blasting. It was estimated that the actual work done was lessened by one half in consequence of insufficient ventilation, a serious loss on the labour of three thousand men. Yet 4,476,000 cubic feet of air were being pumped into the heading daily. The ventilation in the St. Gothard after the completion of the tunnel is, contrary to anticipation, performed by Nature alone. A current of air is set up by the difference in barometric pressure which exists at the two sides of the Alps.

A very remarkable and unusual experience in the St. Gothard was the sinking of about a hundred yards in length of a completed portion of the tunnel. This was due to the strata there being composed of calcareous materials which swell and disintegrate with absorption of water. Ultimately the section was enlarged and lined thickly with granite masonry.

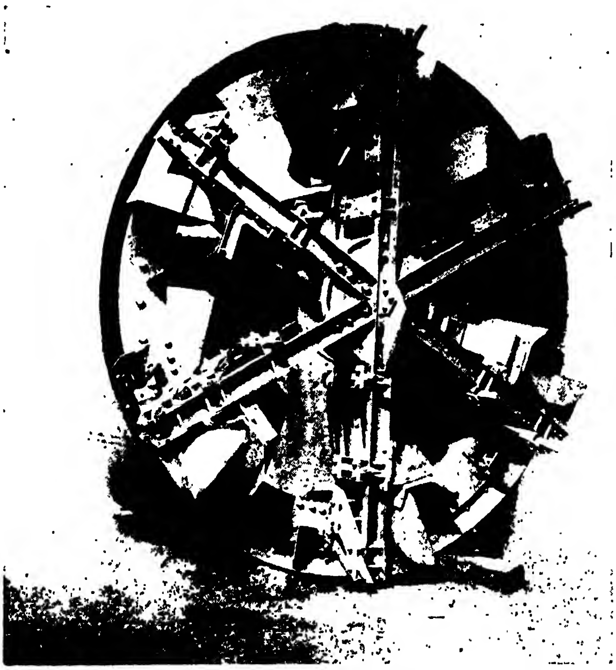
How is it that when tunnels are bored from opposite ends, as is commonly done, they meet exactly at the centre? A marvellous fact, though true. When the Simplon Tunnel was joined up, the walls corresponded exactly, and the height of the floors showed a difference of four inches only! And this in a length of 12¼ miles! And yet the rails were 175 feet lower at the southern end than at the northern. Moreover, the length, which could not be measured directly, with mountains towering from 5000 to 7000 feet above, was estimated correctly within a length of 2 mètres say, 6 feet 7 inches. When the men working from both ends of the St. Gothard Tunnel met at the centre, the walls differed only by 20 centimètres, or, say, 8 inches, and the floors by half that amount only. In the Severn Tunnel the headings from the Welsh and the Gloucestershire sides met exactly. Our much shorter English tunnels were constructed before any experience had been gained in this kind of work. Yet in Box Tunnel the deviation in a measured length of 1500 feet was only 1¼ inches; in the Bletchingley Tunnel the deviation was 1 inch. But in these cases the aligning is done by the ventilating shafts, down which plumb-lines are dropped from the course of the line laid down on the surface.

Generally the method of aligning a tunnel when shafts cannot be sunk may be described thus: A transit instrument is set up at some distance away from each end, on an observatory built of masonry. This

instrument comprises a telescope with cross-hairs, combined with divided circles and a level. It can be directed to any angle, horizontal or vertical, and sights taken through it until the middle of the crossing hairs aligns an object. This supplies a means for locating a centre line corresponding with the axis of the tunnel, and also for checking the boring as it proceeds. The rest is a matter of careful working. If a mountain is not inaccessible, an observatory is placed on the top over the route of the intended line, and two other observatories at several hundred feet away from each end of the tunnel. When the transit instruments are aligned with the central observatory, which is done with posts carrying signal-discs, or bright lights, as that from magnesium lamps, the transit telescopes can be tilted downwards and rods adjusted in the same plane, and wires adjusted by the instruments and stretched taut along the line will give the "back-sights" for working into the tunnel. Several signal-posts are erected on the level, and low down on the mountain sides, in order to lessen the liability of errors in observation. As the tunnel is driven, additional signal-posts are erected within it, with fine lines illuminated, and the transit instruments at the back-sights are tried on these.

After a tunnel is constructed, much engineering skill has to be devoted to the question of ventilation. In the ordinary railway tunnels, air-shafts at intervals provide sufficiently well for escape of smoke and foul gases, and the draught induced brings fresh air in at the ends. In the London tubes the draught of the trains, though considerable, is not alone sufficient, but fans are employed to change the air. A fan at Shepherd's Bush draws the foul air through the "Central" right away from the Bank. Fans at Waterloo exhaust the air from the Bakerloo tube at the rate of a million cubic feet per hour. In the Simplon a small tunnel is provided parallel with the main one through which the trains run, solely to provide for ventilation.

The greatest difficulty and danger which arises in boring long tunnels is due to the uncertainty as to the character of the strata which will be encountered. Though many borings are made, these do not always reveal the presence of the faults which are subsequently discovered. The most dreaded of these consists of loose, sandy materials, and water. Boring through stiff clay, or drilling rock, is straightforward work, if not exactly easy. But the irruption of the loose materials and of water is always dreaded. Practically all the disasters which have occurred in tunnel-making have arisen from one or both of these sources.

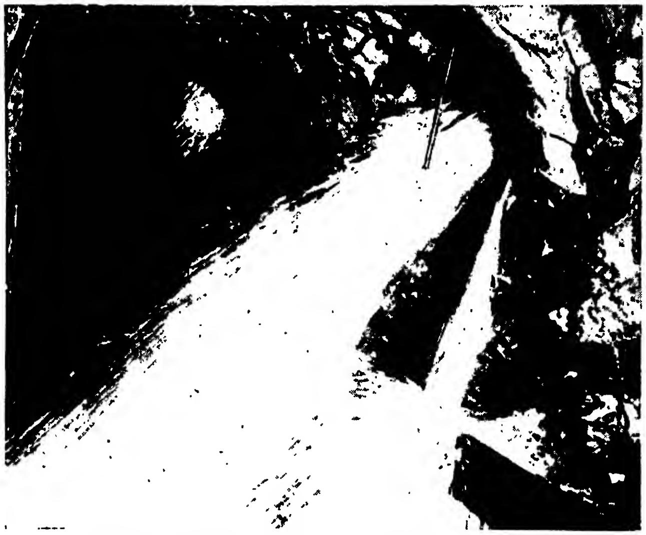


THE FRONT VIEW OF AN AUTOMATIC SHIELD

Though, in general, geologists are able to determine the nature of the strata through which tunnels will have to pass, this is not wholly reliable. The presence of faults and fissures, and of water, are the uncertainties that cannot be detected. Careful borings were made in the Severn at intervals of a few yards right across, but the works were stopped for a whole year by the flooding of a heading. Borings cannot be taken in the Alps, but geologists stated very approximately the character of the strata which would be met with. On the northern side of the St. Gothard Tunnel, 6000 feet of solid granite was drilled in the dry. But on the southern, or Airolo, side the discharge of water from the yielding and disintegrated rock was 4000 gallons per minute! Often the drilling-machine frames had to be laid in a torrential stream 20 inches deep. The

men worked incessantly in a tropical rain descending from the roof, while frequently new solid jets burst out from floor or walls, as thick as a man's arm, with sufficient force to knock a man down. This kind of thing alternated with varying intensity from day to day.

To add to the difficulties, the workings were always at a high temperature, which was increased by the blastings of dynamite, of which nearly 500 ounces went to a charge, so that 85 deg. Fahr. and over was recorded. The heat on the south side was higher than that on the north, due, probably, to the greater height of the mountains there. Almost worse than this is the inrush of water from hot springs, such as happened in the Simplon Tunnel. These would knock down the workmen; and though provision was made to carry off the water, its temperature raised that of the air so high that work became impossible. Cold water was then brought to mix with it, and lower the temperature, before work could be resumed.

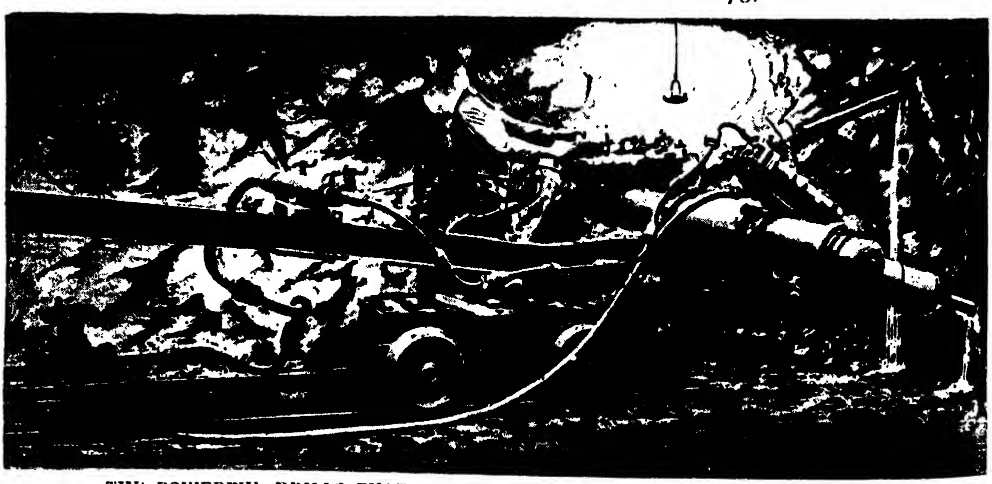


WATER RUSHING INTO THE SIMPLON TUNNEL

When loose earth is encountered, if it is not complicated by the inrush of water, supporting timbers are put in until the regular lining can be inserted. But in sub-aqueous tunnels the one usually causes the other, and then the entire length of completed tunnel becomes flooded, and the workers are drowned. This cannot happen, however, if air is used under sufficient compression to resist the inrush. The deeper the tunnel, the more must the air be compressed.

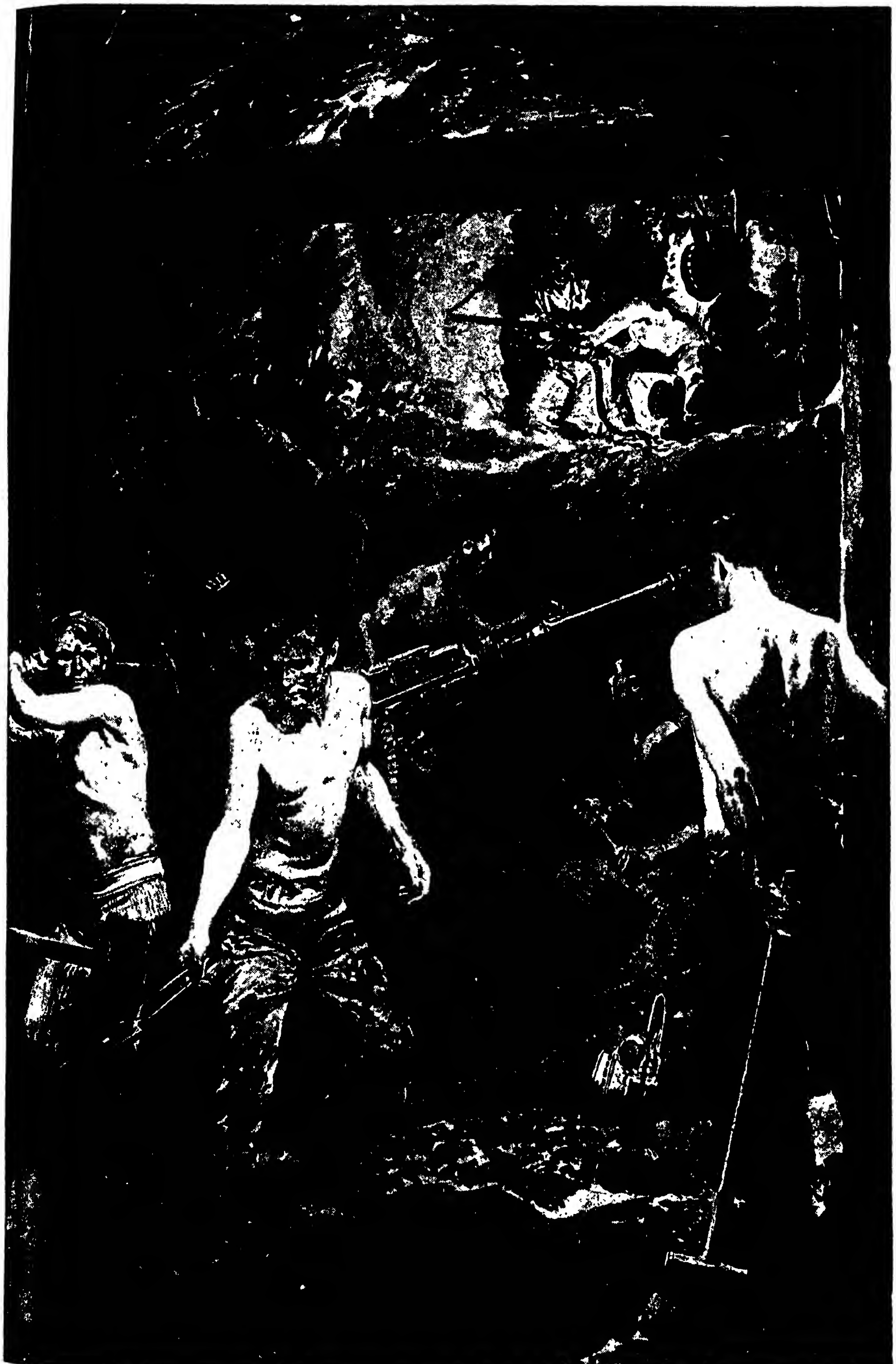
Compressed air has been used to drive water out of a drowned tunnel. This was done in one of the Glasgow tunnels into which the water burst in 1892. In about twenty-four hours it was forced out by the compressed air, which drove it up high above the surface of the river, into which it fell in cascades. But this was almost a unique method. Commonly, flooded workings have to be pumped dry.

Water was the most persistent cause of trouble in the making of the Severn Tunnel. The sinking of the first shaft on the Welsh side occupied the whole period from March to December in 1873, but the tunnel was



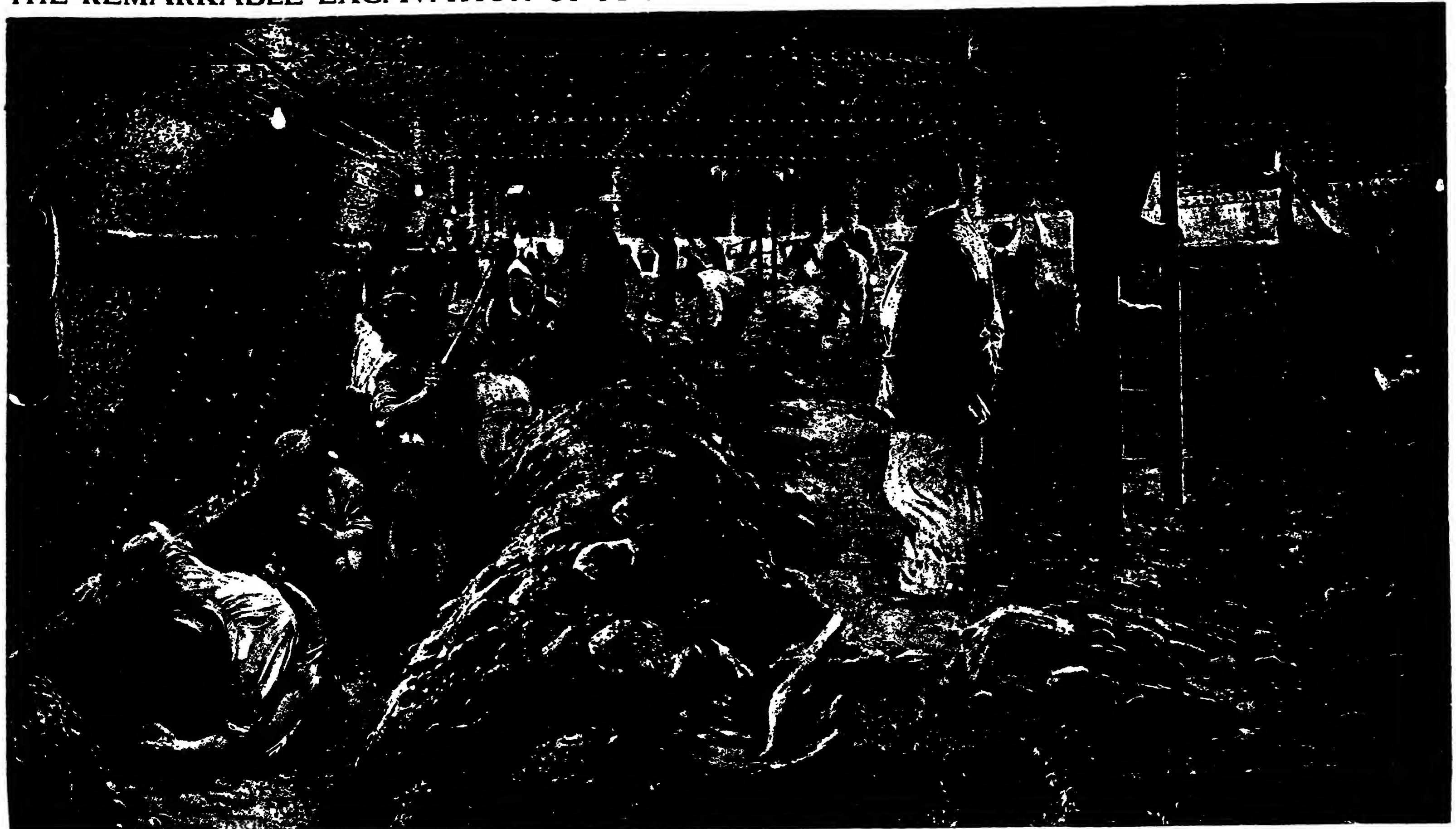
THE POWERFUL DRILLS THAT PIERCE THE HARDEST ROCKS OF THE EARTH

THE HUMAN MOLES AT WORK IN THE EARTH



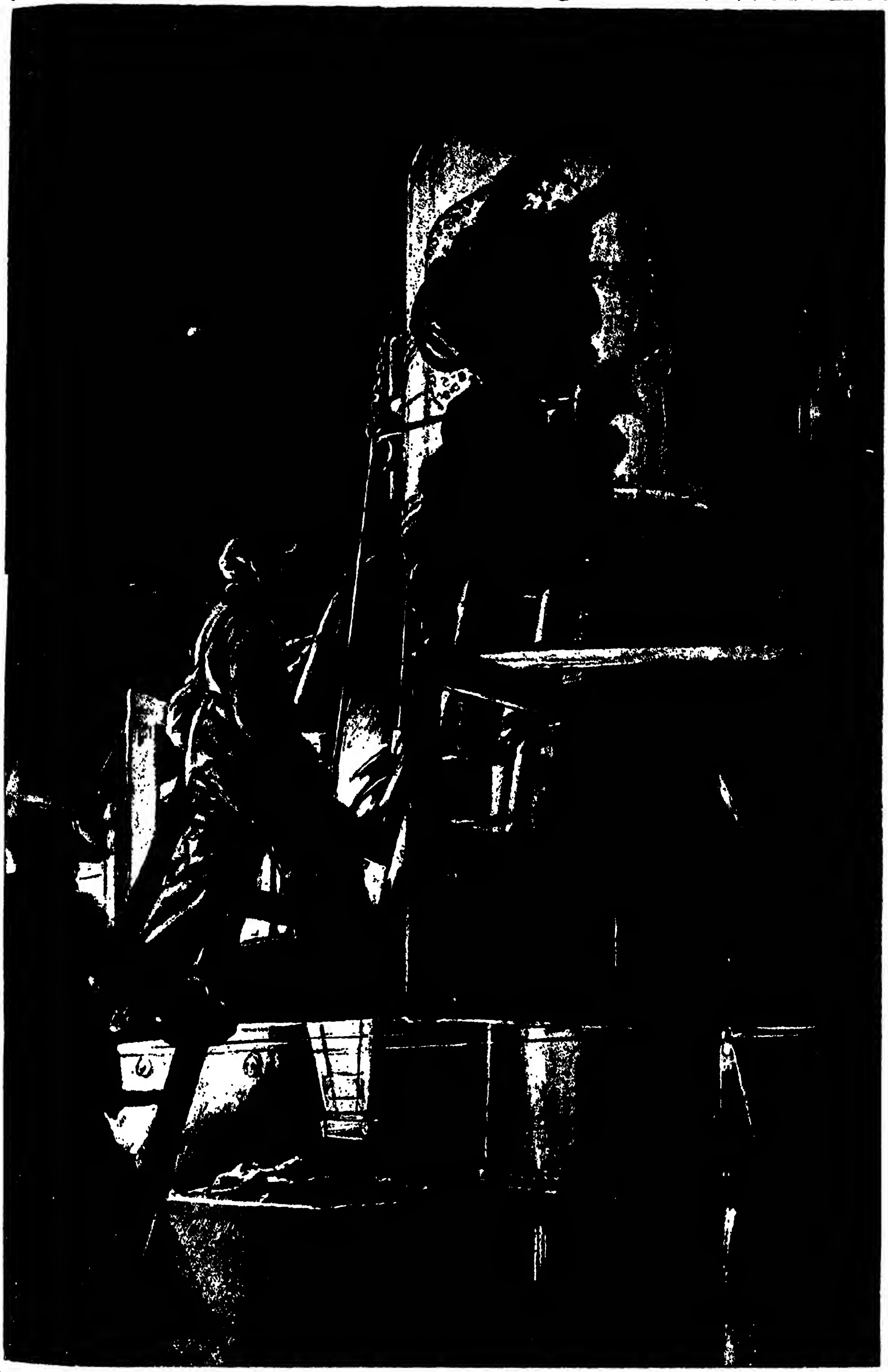
We here see the processes of tunnel-boring as carried out in Switzerland, where a line has pierced the Loetschberg between Kandersteg and the Rhone Valley, a little to the east of the Gemmi Pass. The sections were approaching within hearing from either side at the time represented in the picture

THE REMARKABLE EXCAVATION OF A TRENCH ACROSS THE BED OF THE RIVER SEINE



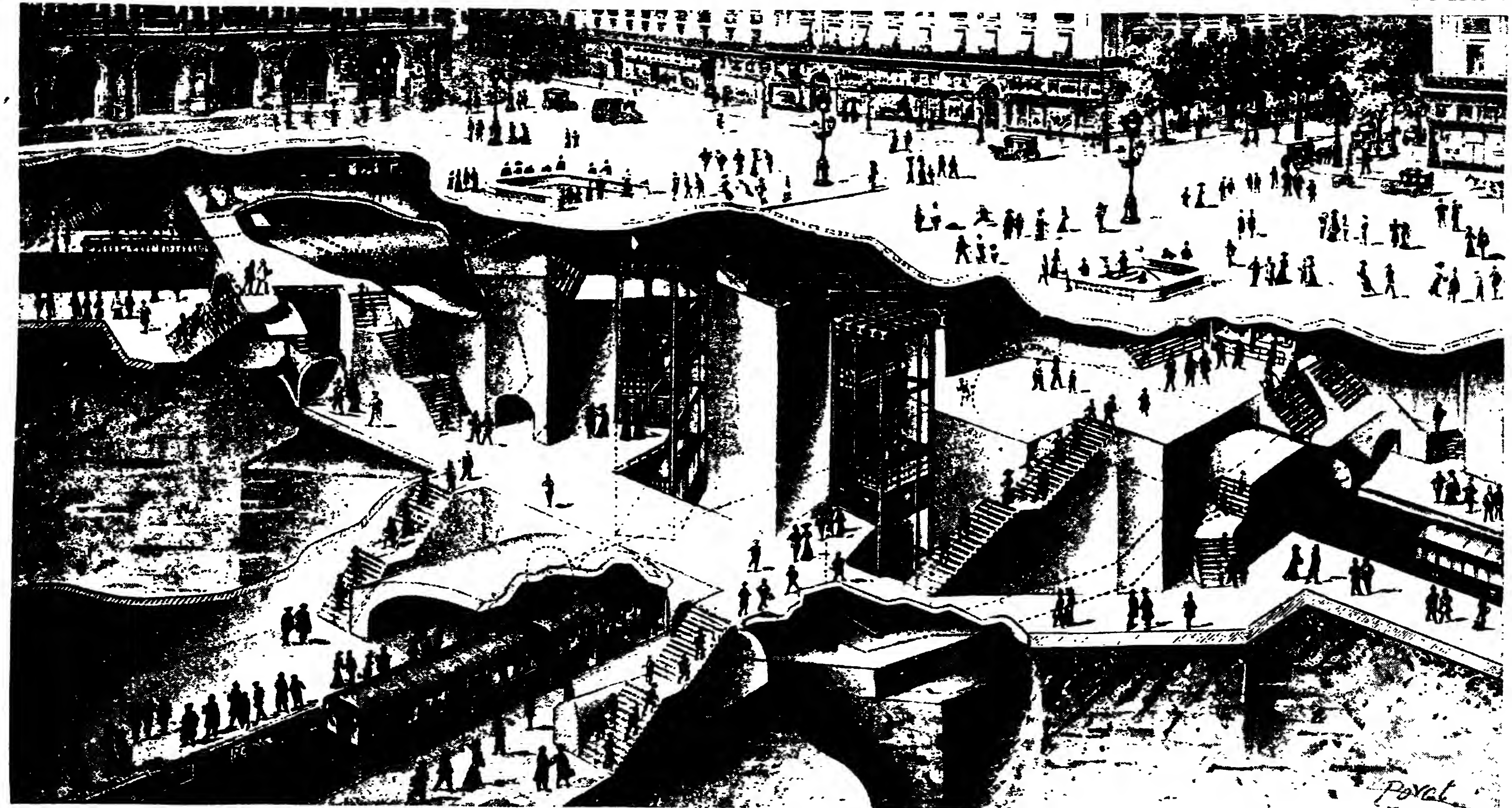
Instead of sinking a shaft and boring with a shield beneath the bed of the river Seine the engineers of the recently built Paris Underground constructed the tunnel in sections, with the sides projecting below as flanges and forming a cavity in which men were able, by means of compressed air, to excavate downwards, the huge tunnel gradually sinking until the top was below the level of the river bed.

ON THE WAY TO WORK UNDER WATER



Workers in compressed-air chambers under the tunnelled Seine are here seen entering the pipe which leads down to the excavations through successive stages of pressure. The completion of the descent into the working chamber may be seen on the opposite page.

THE COMPLEX NETWORK OF RAILWAYS THAT LIES BELOW THE HEART OF PARIS



Crossing each other beneath the boulevard in front of the famous Paris Opera House run three railways. This drawing shows the complex yet compact arrangement of the stations with their approaches and inter-communication. There are nearly 400 stairs at this spot, and the wells of the lifts are over sixty feet deep.

not completed until 1881. At about 45 feet down this shaft, a spring was tapped which poured out 12,000 gallons an hour. Three or four yards lower down another spring burst out, yielding 27,000 gallons per hour. This shaft, when finished, was 200 feet deep. Again a spring was tapped, and a volume of about 360,000 gallons per hour rushed in in a stream 7 feet wide and 12 inches deep, filling the works for 355 yards from the shaft. The pumps available could only deal with a quarter of a million gallons per hour. Fresh pumps were installed to deal with 460,000 gallons per hour. Before these could be fully utilised, some watertight doors a quarter of a mile away from the shaft would have to be closed. A diver, at great risk to his life, made his way through the water and closed the doors. He carried a knapsack containing materials for generating oxygen, and was under water for an hour and twenty-five minutes. Afterwards, the works were pumped dry, and the tunnelling resumed. During the time when the works were flooded, the River Nedern lost nearly all its water, and all the springs and wells for miles around ran dry. After the doors were closed, and the escape of water stopped, the springs, wells, and river returned to their normal height. Afterwards, when the headings had been driven to within 130 yards of each other, an irruption of water from the river stopped the work for several weeks. The opening was filled up with puddle-bags and the workings cleared.

To meet death in a tunnel must be a terrible experience. Yet few long tunnels have ever been constructed without the sacrifice of some lives. In the Hudson River Tunnel twenty men met their death in one July morning in 1880, drowned in a torrent of water which brought down the roof and flooded the works. The death-rate rose alarmingly during the progress of the St. Gothard, consequent on chest complaints and other internal diseases, and anæmia. From the latter cause alone it became necessary to dismiss ninety men in the first three months of 1881.

THE TIDAL WAVE THAT SWEPT INTO THE WORKINGS OF THE SEVERN TUNNEL

The loss of life on the St. Gothard was appalling, totalling 800. When the Simplon was begun, better measures were adopted. A supply of air fifty times in excess of that provided in the St. Gothard was insisted on. And, instead of allowing the men to come out of the warm workings directly into cold air, a covered passage led the way to a restaurant, where they had their clothes dried and warmed, ready for the next day's work. Here they rested for half an hour, and partook of a substantial meal provided by the contractors.

THE LARGEST RUBBER TREE IN THE WORLD

THE TREE THAT HAS MADE A NEW INDUSTRY, AS IT APPEARS IN THE FORESTS OF FLORIDA

RUBBER'S STRANGE STORY

The Romance of a Boring Beetle, a Tree's Defence, and Wealth and Comfort for Mankind

WILL ALL THE WORLD WALK ON RUBBER?

TYNDALL'S super-man, surveying the fiery vapour from which our planet evolved, and predicting the rise of life and its development into thousandfold forms and refinements, would probably have made himself look rather foolish over details. He must have gone astray on the point of locomotion and communications. Had man and his mind and its works come earlier in the story of creation, had he developed as early and rapidly as plant life and insect life, the face of Nature would have been largely changed. It would have been a calamity if a single recent discovery had come when the battle for life between plants and insects was earlier in progress.

Herr Franz Muller proposes by electricity and a chemical compound to rid trees from parasites from root to branch, and to feed them with nourishment as cattle are fed for a show. The invention is stated to possess special potentialities with respect to the rubber tree and plant. Had that scheme come earlier there might have been no such thing in the world as rubber. In that case there would have been no bicycle, no motor-car, no trans-oceanic cables, which latter are dependent for their insulation upon rubber products. Genius and invention, arriving untimely, would have rendered it unnecessary for Nature to devise one of her most interesting forms of defence for the protection of certain varieties of vegetable life.

The existence and purpose of rubber are a mystery to the forester, but the entomologist, studying the life of insects, holds the key to the secret. He knows, he believes, why the precious latex is there, though the forester does not. On the face of it the existence of the substance is a little puzzling. It is no part of the sap; it has absolutely no relation—normally, at any rate—to the nourishment or growth of the tree. Like the frightful carnivorous teeth in the manlike ape, which is a herbivorous animal, this latex is, in the main, a defence.

It sallies forth from a breach which an enemy has made in the bark of the tree. It may poison or entrap the intruder. It certainly closes the breach, heals the wound, and renders the tree able to pursue the healthy course of its life. The latex, or milk, of the plant or tree coagulates on reaching the air, as blood coagulates to prevent our bleeding to death from the wound by which it emerges. It possesses its pliability in order that with the swaying and tossing of the tree in storm or wind the closing of the wound may not be broken open, as would happen were the covering brittle like sealing-wax. The latex, flowing from a puncture, prevents the ingress of the original intruder; it also defies the deadly fungus that attacks any morbid area in a tree. Rubber gloves keep the operating surgeon's hands immune from the deadliest bacteria; rubber plasters enable a wounded tree to combat the beetle and fungus spores.

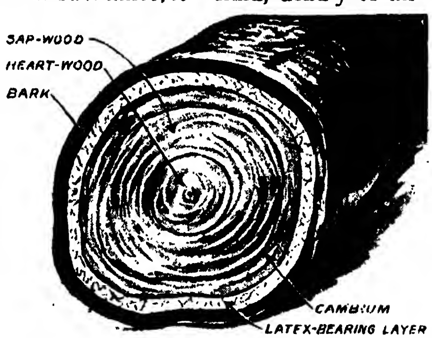
For it is the beetle, the wood-boring beetle with its powerful saw, that the rubber tree is specially armed to fight. To that small insect, not to any creative merit of our own, do we owe all the rubber that is in the world. The wood-borers puncture the bark and lay their eggs in the wood of trees. The eggs develop into larvæ, which devour the living substance of their host. Trees that have been drained of rubber are found enfeebled and dying, riddled by the wood-boring beetles. In such case the tree, bereft of its only weapon, is as an unarmed man confronting a ravening carnivorous enemy; or, rather, like a man lying out at night, without the protection of a mosquito-net, in the haunts of the deadly tsetse fly that carries the germ of sleeping sickness.

TAPPING THE PARA RUBBER TREE IN ITS NATIVE FORESTS IN SOUTH AMERICA

In the left-hand picture the native gatherer is seen in the act of tapping the inferior grade of rubber milk, which collects about the roots of the tree. In the centre picture we have a closer view of the tree, showing the cups that catch the better grade of milk, known as Seringa. This milk is collected in cans by the gatherer, as seen in the right-hand picture.

The rubber tree is armed, in the words of our old Volunteers, for "defence, not defiance," and the milky fluid flowing through its bark is the armament upon which its safety depends. Because there exist certain beetles having strong thrusting implements with which they are able to bore into trees to let their larvæ live and feed upon the body of the tree—as, within more restricted limits, the larva of the ichneumon fly lives within and consumes the body of the hapless aphis or greenfly—because of this we have tyres for motor-cars and adequate insulation for cables that cross the ocean-bed and carry a message round the world in almost as short time as that in which it is written.

It is a fascinating story that the entomologist-botanist thus reveals; but of course there is nothing in Nature quite without a parallel. If rubber, a fluid flowing within the interior of a tree, be a wonderful substance, it is not more so than the silk which spider and caterpillar produce from within their small bodies. Every young microscopist, when he first begins his studies, makes an effort to dissect the spider, with a sort of idea that he will discover the silk, of which it spins its web, neatly reeled up within the little creature's anatomy. But he is disappointed; and then he thinks that he must have chosen the wrong species, or perhaps the wrong sex, for he discovers nothing but an accumulation of dark, viscid fluid, where he had expected to see a silk factory in miniature. But that viscid fluid is the substance of which the spider spins its web.



CROSS-SECTION THROUGH A RUBBER TREE

The silk a duchess wears is, when within the body of the silkworm, a similar fluid, but after it is drawn out and coagulated it is the strongest dress fabric known to man. We have mastered the secret of the silkworm, and can now produce artificial silk—from paper; we have mastered the secret of the composition of rubber, too. We have broken it up into its constituent elements, and can build these artificially as we can build up artificial indigo. But whereas the latter killed India's trade in the natural article, natural rubber remains unaffected by the discoveries in the laboratory, for the sufficient reason that it costs more to make rubber than to grow it. Cheap synthetic rubber may eventually come, but the hour and the man have not yet arrived, and we still rely upon that first and most economical of supplies—Nature's own. But, as we shall see, we have enormously helped her to increase that supply.

There, then, is the strange story of the genesis of rubber. It has its parallels in the productions of the larvæ of certain insects, though the aim and application are different. It has a closer analogy in the defences of many other plants in which a wound is followed by the discharge of a virulent poison. Opium, that has blighted so many human lives, is a development corresponding to the latex of the rubber-tree.

That fluid resides, however, not in the stalk of the plant, but in the great seed-head. When the latter is wounded, there issues from the scratch or puncture a milky fluid, deadly to an insect, and at the same time serving, by rapidly drying, to close the wound. And so, for ages past, thousands of human beings have been making a living by artificially wounding poppy-heads and stimulating a flow of the juice, to pick it off when it has hardened, work it into cakes, and convey it to the factory for conversion in commerce into the beneficial opium of medicine or the destructive agent of the drug fiend.

But had man with his invention for the artificial extinction of the parasites infesting the interior of trees, their roots, their bark, their trunks and branches—had he come earlier, when the battle between plants and animal life was in its beginning, there would have been no need for rubber. Nature never bestows an unnecessary defence. And had there not been this natural defence against insectile attack, we should to-day lack many of the most important aids to civilisation, and, incidentally, the Stock Exchange would have missed the greatest "boom" known perhaps within the life of the present generation.

The first use of rubber was one of those primitive fundamentals of observation and ingenuity such as in early times gave man the fallen log for a raft on which to take an experimental journey afloat. The inaugural aquatic adventure was probably a

sporting trip; the first use of rubber by man was undoubtedly for pastime. Columbus, upon his second journey to Haiti, found the natives playing with balls made of the substance, and he noticed with surprise how the playthings bounced. But he little dreamed that the natives' toy possessed potentialities of wealth greater than any of the concrete riches he saw and coveted. Mines become exhausted and cannot be renewed, but rubber goes on growing and re-creating itself from seed.

The Haitians were wiped out of existence in the course of a generation by the abominable cruelties of the Spaniards, and their places taken by negro slaves, so there was nothing in the way of knowledge as to rubber to come from the island in which a European first saw the product. Brazil afforded more information. The Portuguese, who seized the territory in 1500, found the natives using rubber squirts or syringes; and Torquemada, a century later, found the rubber in use among the Spanish colonists as a waterproofing preparation for their cloaks.

A TAPPING-KNIFE, DESIGNED BY DR. HUBER, USED FOR THE BRAZILIAN RUBBER TREES

It was not, however, until the fourth decade of the eighteenth century that the nature and use of rubber became known in Europe, when La Condamine read a paper on the subject before the French Academy. Even then the only purpose to which the product was put in Europe was that of erasing pencil-marks. The native name "caoutchouc" was abandoned in favour of the "Indian rubber"—rubber for the reason named, "Indian" because the natives of South America were first so called in the belief of the finders of the New World that America was India.

Rubber first became a valuable product when Charles Macintosh, a Glasgow chemist, in 1823, invented the waterproof which to this day is called by his name. But nine years later in America, and ten in England, the master secret, the art of vulcanising rubber, was discovered—across the Atlantic by Goodyear; in England, independently, by Hancock. Vulcanising converts the raw product of the tree into the article of commerce. Mixed with certain proportions of flowers of sulphur, and submitted to the requisite degree of heat, rubber can be reduced to a substance resembling horn—the ebonite or vulcanite of commerce, from which a multitude of articles are fashioned—from pipe-stems to surgical appliances, from gramophone discs to the gums of artificial teeth, from the acid-resisting trays of the chemist and photographer to the transmitter and receiver of the telephone.

On the other hand, by modifying the proportions of rubber and sulphur and the degree of heat in which amalgamation is effected, the manufacturer gives us the pliant, elastic rubber which forms a tyre for a motor-car or bicycle, springs and buffers for a railway, indispensable parts of the telegraph, the elastic that controls the mechanism of millions and millions of the only toys known to children of the poor, the surgical bandage, the air and water bed, hose-pipes, and a host of articles serving in daily life without which civilisation to-day would seem lost. Rubber is insoluble in water, and cannot be penetrated by gas or fluid. Its properties are unique as its purposes are manifold.

All this wealth-giving substance is, then, merely the coagulated juice of various tropical trees and vines. The finest rubber came, until but recently, from Brazil, from trees growing wild in the vast forests—not forests of rubber-trees, but rubber-trees scattered here and there, occasionally in clumps, but more frequently occurring as single trees in the midst of many other growths. It occurs in great quantities, too, in Central America and the northern parts of South America. India supplies rubber from the well-known species of fig, *Ficus elastica*, and there are indigenous vines in Borneo, in the Eastern Archipelago, and, of course in Africa, where the frightful stories of the ensanguined Congo are too fresh in mind to permit forgetfulness of that hateful

SKILFUL CUTTING OF A RUBBER TREE

THE METHOD OF REMOVING THE BARK TO PROMOTE THE DEFENSIVE FLOW OF THE MILK

trade. But the quantities obtained outside South America were, as said, until recently, practically negligible. Brazil furnished the supply and created the demand elsewhere. But there is a stirring romance in the story of the spread of rubber from the New World to the Old, from the West to the East.

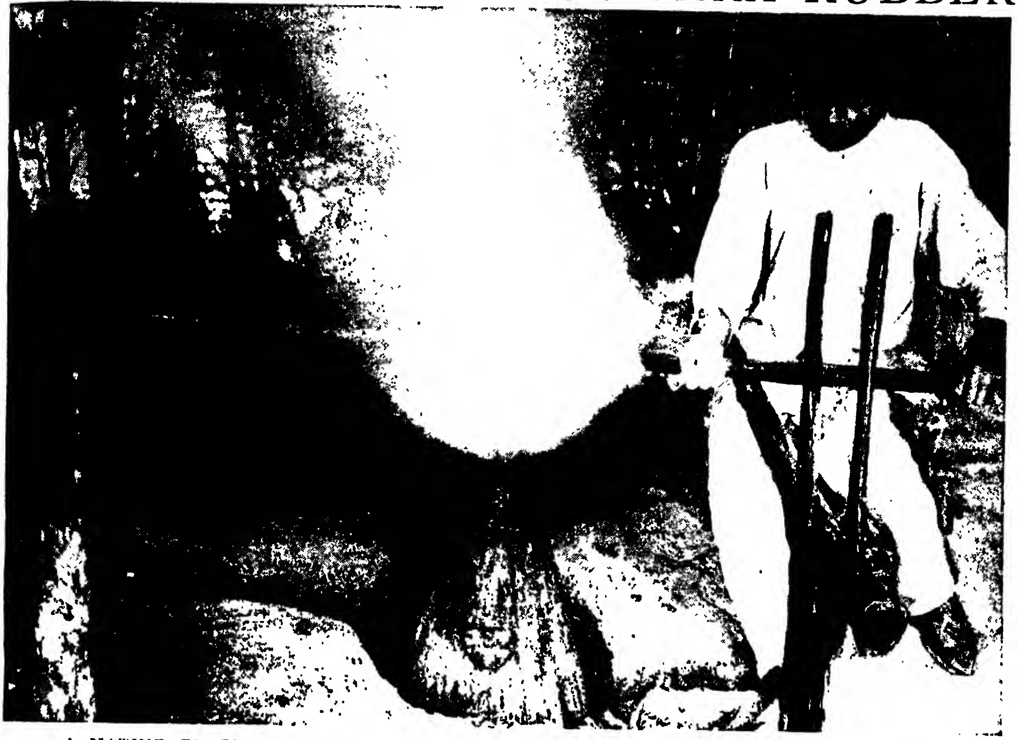
That hero of Empire Sir Joseph Hooker, who died last year, realised, when the world was wrestling with its first glimpses of the "Evolution of Species," that there was a great future for rubber in the East, if only he could get it from the West. And it fortunately happened that in the West there was, in Mr. H. A. Wickham, a man imbued with the same notion. He proposed the deliberate cultivation of wild rubber-trees, but no one in the City would listen to him. But he met Sir Joseph, and the two put their heads together, with the result that, unknown to the world, Mr. Wickham was given a Government commission to go out to Brazil and collect seed of the famous *Hevea brasiliensis*, the most famous of all the Para rubbers. Para, by the way, is the title of all the best grades of rubber, of whatever species of tree, exported from the town of Para.

The quest of the seeds was as great an adventure as Sir Clements Markham's expedition in search of the cinchona, from which the quinine so essential to the health of India is made. Brazil had her millions of acres of trees, but she jealously conserved her treasure, and the seeds had to be surreptitiously collected, smuggled on board a steamer, and passed through the Customs as precious botanical specimens for Kew Gardens. This was true to the ear if not to the real intention, for Kew has never received a more precious consignment.

Seventy thousand seeds were thus brought to England. They were for India, but so perishable are the seeds that they could not stand the voyage to the East. A telegraphic message to Kew caused the summoning of all hands to the Gardens for urgent duty. A man drove up late at night in a hansom cab, carrying a sack. In

METHODS OF EXTRACTING RUBBER FROM HIGH UP THE STEMS OF THE RUBBER TREES

SMOKING THE FAMOUS PARA RUBBER



A NATIVE BRAZILIAN GATHERER SMOKING RUBBER OVER A FIRE OF PALM-NUTS

POURING THE RUBBER MILK ON THE COLLECTING BALL DURING THE SMOKING PROCESS

the sack was the necleus of undreamed fortunes for the East. The sack contained the seeds, and the gardeners worked all night setting them. A fortnight later 1700 tiny plants were showing their heads in the forcing-houses. In due course the plants were dispatched overseas, going in miniature hothouses, to Ceylon, to Perak, and elsewhere. In due season they developed into strong trees, bearing seed of their own; and to-day the innumerable host of hevea rubber-trees growing in the Eastern tropical countries attests the success of the experiment. The rubber companies in those lands have now an authorised capital of many million pounds.

The work of collecting the rubber varies according to locality. The principle is, however, the same. A tree is tapped by the making of a gash in the bark. This may be vertical, circular, or diagonal, according to local custom. A small receptacle, either of metal or clay, is affixed to the trunk of the tree, preferably by means of clay or mud, in such a position that the resultant flow of latex shall be caught. The tapper calls towards the close of the day, and collects the contents of his cups. These are emptied into a larger receptacle, and roughly prepared for market.

The latex is caused to coagulate into solid masses either by manual methods or by machinery, so that the pure rubber becomes separated from any watery solution which may accompany it, as cream is separated from milk. There are many processes in operation for the preparation of rubber for market. In some the latex is stirred about with a paddle over a smoky fire, or collected in strips upon sticks, or placed in a machine which acts upon the principle of the milk-churn. By whatever process, the albuminous matter contained in the latex is apt to cause rapid decomposition, so it may be necessary to add a sterlising chemical.

The value of rubber, apart from the excellence of its inherent qualities, is determined by its purity. Thus the rubber which is preserved from any admixture of foreign bodies is naturally best. That which contains fragments of bark scraped from the tree, or dirt and leaves gathered up from the soil on to which the substance has fallen, is naturally less sought, as it holds less pure rubber and occasions greater expense in cleansing in the factory. Now that rubber-planting has becoming a great organised industry, employing many millions of capital, the tendency will be more and more to eliminate the dirty raw product. Even as it is, the best rubber, on passing, as it must pass, twice through the washing, rolling, and squeezing process, loses from 15 to 20 per cent. in weight, while the inferior qualities surrender as much as 60 per cent. of impurities in the process.

A B C D

FOUR EXAMPLES OF WILD RUBBERS AND THE SAMPLES THAT THEY YIELD

The wild rubbers are shown in the top row, and the extracted rubber in the lower row. In A, the Guayule shrub and its produce is shown; in B, the Landolphia vine; in C, curious bulbs found in the ground in Portuguese West Africa; and in D, the Congo "fingers" which are received full of bark, and need more treatment for the production of the sheet and block rubber shown below them.

The raw material in this process is passed between heavy iron rollers, smooth or grooved, which, placed horizontally side by side, revolve inwards at different rates of speed, while a constant stream of water plays over the rubber. By this means all vegetable impurities, sand, and other mineral matter, as well as any chemical reagent used in the coagulation of the latex, are crushed or squeezed out and washed away by the water. The rubber comes out either in sheets or in fragments, according to the form in which it has been first prepared, looking like blotting-paper with a characteristic shrivelled appearance.

Drying follows. At first it was thought that cleansed rubber should be dried like the buds of the clove-tree, slowly and by natural process. We know now, however, that this

THE RUBBER INDUSTRY ON THE CONGO

Rubbers from different parts of the world have different values according to purity. The material obtained from the Congo is made impure by mixture of dirt and woody fibre. Sliced and put in sacks, it is beaten vigorously with heavy cudgels by the natives to remove these foreign substances, as seen in the picture. Its trade value, however, remains low.

CLEARING THE SOIL IN FOREST COUNTRY PREPARATORY TO PLANTING RUBBER TREES

A NEW RUBBER FOREST BEGINNING TO RISE OVER THE RUINS OF PRIMEVAL GROWTH

ORDERED GROVES OF RUBBER TREES

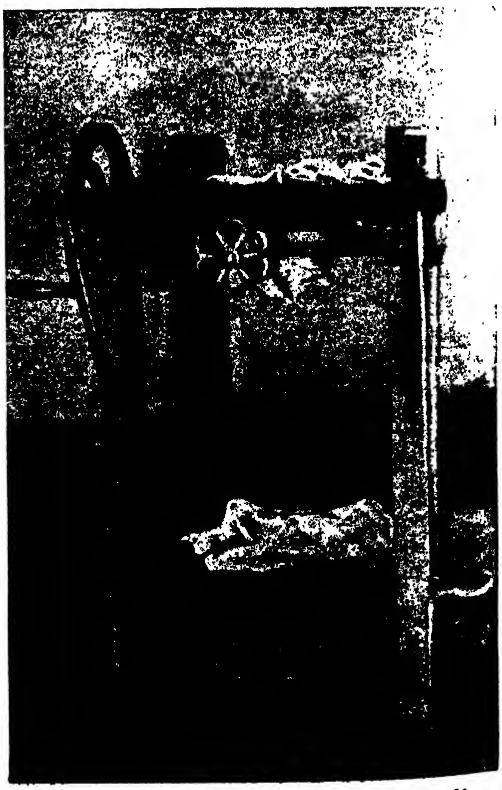
RUBBER TREES AT DIFFERENT STAGES OF GROWTH IN A MALAY PLANTATION

NATIVES AT WORK TAPPING RUBBER TREES ON A RUBBER ESTATE IN THE MALAY STATES

THE PURIFYING OF RAW RUBBER

THE METHOD OF COAGULATING RUBBER MILK IN PANS

A SPONGY MASS OF RUBBER ON A MODERN COAGULATING MACHINE



A MACHINE THAT EXPELS WATER FROM SPONGY RUBBER

IN THE RUBBER FACTORIES OF THE EAST

THE MANUFACTURE OF LACE RUBBER

DRYING BISCUIT RUBBER

MODERN MACHINERY MAKING CRÊPE RUBBER, WORKED BY NATIVES IN THE MALAY STATES

The bottom picture on this page and those on pages 1222 and 1226 are by courtesy of Messrs. David Bridge & Co., Ltd., the well-known engineers. The top pictures on this page and those on pages 1224 and 1230 are from "Pará Rubber," by permission of Sir Herbert Wright. Acknowledgment is also due to the Malay States Development Agency, Messrs. C. H. Kerr, F. Holloway, I. Etherington, H. F. Macmillan, and Underwood & Underwood.

method leads to oxidation, so the drying process is hastened, either by exposure to brisk draughts of air or by use of vacuum chambers. The rubber is then stored in a dark, cool place, ready for any purpose which the manufacturer may choose.

Those processes are as multifarious as technical, for the inexhaustible utility of rubber has called into existence a new and enormous industry producing clothing, utensils for the laboratory and the home, belts for machinery, washers and rings for engines, and so forth almost indefinitely. The rubber industry is one of the most notable in the world; and it is a striking fact that, though 10,000,000 pounds of rubber were produced during 1909 in the British Empire alone, so heavy was the demand that the best Para, which in 1908 had been as low as 2s. 8d. per pound, rose to over 12s. per pound.

Less than forty years ago the amount of rubber required by the civilised world did not exceed 5000 tons. That total consumption is now increased at least twenty-fold. Although more than half this amount comes from the northern half of South America and Central America, the proportion received from the East—from Ceylon, India, the Malay Peninsula, and the East Indian Archipelago—is rapidly increasing; and the quality of the Eastern rubber is giving it a favourable place in the market, notwithstanding the fact that it is the produce of young trees—and rubber improves with the age of the tree from which it is collected.

Rubber made the motor-car possible; and the demand for tyres has been one of the main factors in causing a shortage of supply in the market, and thus inducing the sensational boom we have witnessed. But that boom has led to the planting of millions of trees in the tropical lands of the British Empire and elsewhere; and those trees, when they come into bearing, as they will in the course of the next five years, will produce huge quantities of rubber. By that time the best rubber should return to 2s. per pound. Then will follow another revolution—rubber roads, or, rather, roads made of a rubber composition, resembling asphalte in appearance but retaining the resiliency of rubber. Roads can be economically made of this substance with rubber at 2s., it is stated; and when that time comes the demand upon the rubber planter will be as much in excess of the existing demand as that of 1910 was in excess of that of 1890.

Rubber is to be the quarry of the future road-maker in the great cities. The white walls of Old England are but the fossil remains of billions of creatures that once had life, and all our fuels had a vegetal origin. There would be nothing astonishing in this further extension of a gift of Nature to the service of the lord of creation. But there is a wood-boring beetle at the back of the whole story.

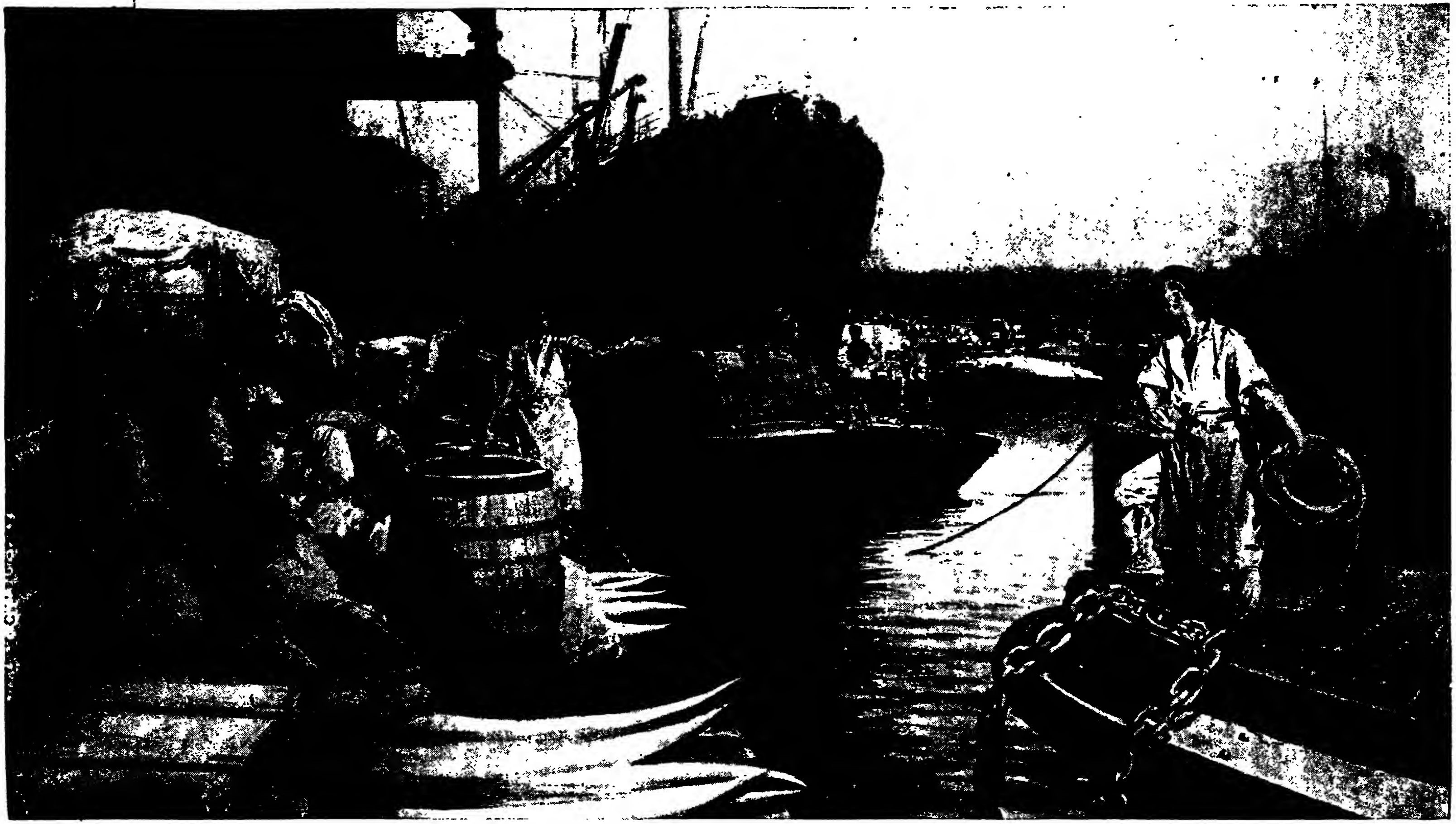
NATIVES BOILING AND CLEANING RUBBER IN A FACTORY ON THE PLANTATION

CARTING RUBBER IN THE MALAY STATES

A CAN OF FRESHLY CUPPED RUBBER ARRIVING AT A FACTORY IN THE MALAY STATES

NATIVES LOADING A CATTLE-DRAWN CART WITH BOXES OF FACTORY-CURED RUBBER

WHERE ENGLAND OFFERS OPEN HOUSE TO ALL THE RICHES OF THE WORLD



The total value of British trade now exceeds considerably twelve hundred million pounds sterling per year, and all the goods which represent that stupendous sum pass through one or other of our docks and employ our shipping.

WHERE OUR TRADE IS DONE

An Account of the Nations With Whom We Do Twelve Hundred Million Pounds' Worth of Trade

WHENCE WE IMPORT & WHERE WE EXPORT

In our last chapter we examined the trade of the British Empire, and saw how vast and important are the dealings carried on between the Mother Country and the Britains beyond the seas. We also traced to what extent we derive our imported supplies of food and materials from Colonial sources, and the nature of the dealings of the various British Dominions and Colonies with foreign nations. We now come to a broad examination of our over-sea trade as a whole, having regard to the sources of our imports and the destination of our exports.

As we have already indicated, the commerce of the United Kingdom is a thing unique. The fate of the nation hangs upon it; and it is not only true, in the words of Napoleon, that we are "a nation of shopkeepers," but that the nation has either to continue to keep shop or perish. It is absolutely necessary to maintain enormous exports in order to win from abroad the imports without which we should be a thinly populated and poor people.

How greatly our vitalising commerce has grown will be seen by the broad sketch by values which is printed on the next page. The values of British imports were not recorded until 1854, but we have a complete record for a century of the values of United Kingdom exports. In the year 1805, British exports were worth only thirty-eight millions; in 1910 the United Kingdom exported at the rate of nearly thirty-eight millions *per month*. In 1805 the whole of England and Wales contained only about twice as many people as now live in the London County Council area; the enormous growth of population since 1805 has been built up—it would be accurate to say, created—by the enormous increase in trade shown in this remarkable record. If the facts are closely examined, it will be seen that while the movement of the figures has been generally upwards, there have been periods of apparent stagnation. These are not always real, for, it must be remembered, the table measures values and not quantities.

The increase in quantities—in bulk of trade—has been even greater than the rise in values suggests. If we take the period 1875-1895, during which British trade values were comparatively stationary, we find, on inquiry, that prices fell so much in that period that the stationary value figures really represent a big addition to the bulk of trade. Since 1895, prices have been rising again, and that rise has contributed to the exceedingly healthy look of the figures of the last three lines of the table. As a minor point, it should be noted that the exports of new ships were not recorded until recent years, and that these, therefore, slightly swell the export column since 1900; it is a small matter comparatively, and is only mentioned here for strict accuracy.

Fortunately, the commerce of the United Kingdom has not merely kept pace with the growth of population; it has actually grown faster than the population, which means that an increasing population has secured a better average livelihood. This, of course, is of the deepest importance. In 1854, the first year in which the value of our imports was recorded, they were worth only £5 10s. 2d. per head of the population; in 1910 our imports were worth £12 15s. 11d. per head of the population. If we turn to exports, we get a similar very satisfactory result. In 1854, our exports (of British goods only) came to £3 10s. 3d. per head; in 1910 they were worth £9 11s. 8d. per head.

Two great leaps in the export column are particularly worth notice. The first is the increase of over £150,000,000 between 1850 and 1875, and the second the *increase*

YEAR.	Total Imports.	Imports Re-exported.	Exports of British Goods	Total Commerce in Merchandise.
	Million £	Million £	Million £	Million £
1805	Not known	Not known	38	Not known
1810	,,	,,	48	,,
1815	,,	,,	52	,,
1820	,,	,,	36	,,
1825	,,	,,	39	,,
1830	,,	,,	38	,,
1835	,,	,,	47	,,
1840	,,	,,	51	,,
1845	,,	,,	60	,,
1850	,,	,,	71	,,
1855	143	21	96	260
1860	210	29	136	375
1865	271	53	166	490
1870	303	44	199	546
1875	374	58	223	655
1880	411	63	223	697
1885	371	58	213	642
1890	421	65	263	749
1895	417	60	226	703
1900	523	63	291	877
1905	565	78	330	973
1910	678	104	430	1,212

of £140,000,000 in the last ten years. The second of these typifies the great rapidity of expansion which has been characteristic of every branch of human activity in the first decade of the twentieth century.

In the last chapter, we saw how the commerce of the United Kingdom was divided between British possessions and foreign countries. We now proceed to show from which countries and colonies we draw supplies, and to which countries and colonies we sell our exports.

On page 1241 will be found what is, perhaps, the plainest statement of this important matter which has ever been compiled. It shows us at a glance where British trade is done; from which countries we draw our imports, and to which countries we send either (1) exports of imported goods or (2) exports of British produce and manufacture. We see which are our best markets, and which are our indispensable suppliers of foods and materials. To the instructed eye, the table is eloquent on all these points.

We begin with the British Empire. We see that, in volume of trade, India stands first, Australia second, Canada third, and that New Zealand and South Africa run close together for fourth place. We need not dwell here upon the details of the trade of these places, as we gave some attention to the subject in the last chapter. It is well, however, to have the facts thus before us in summary while we are considering British trade with the world as a whole.

The trade of the Straits Settlements bulks so considerably because of the supplies of tin which they send us. The trade with Hong Kong is for the most part really foreign trade with China. Ceylon and the British West Indies are the other most considerable contributors to the British Imperial trade total. In all, the total trade of the United Kingdom with British possessions is seen to be worth £329,900,000 in 1910. By referring to the table above, it will be seen that this is almost as much trade as we did with all the world in 1860.

Satisfactory as our Colonial trade is, however, it is far surpassed in value by the commerce we do with foreign countries. As the total for foreign countries shows, our aggregate trade with foreign nations alone in 1910 was worth £882,600,000. It is an astonishing fact, but this is more trade than we did with all the world, foreign countries and British possessions put together, as recently as 1900.

A STRIKING ILLUSTRATION OF RECENT TRADE GROWTH.

United Kingdom trade *with foreign nations only* in 1910	£882,600,000
United Kingdom trade *with all the world in* 1900	£877,000,000

At no previous time has such an extraordinary advance in British trade been recorded.

All the chief countries of the world, and

many of the minor ones, are dealt with in the table on page 1241, and only thirty-five million pounds' worth of trade is left unanalysed in the list.

Beginning with Europe, Germany easily heads the list, with a total trade of £116,700,000. It is an extraordinarily varied trade which we do with Germany. She is a not inconsiderable supplier of raw materials, including zinc, oils, skins, wood-pulp, manures, chemicals, etc. She also sends us a good deal of food in the shape of corn, eggs, fruit, hops, seeds, and especially sugar; our imports of the last-named article from Germany in 1910 amounted to nearly eight million pounds' worth. We also take from Germany a very considerable quantity of partly and wholly manufactured articles, including arms, apparel, polish, brooms and brushes, buttons, cycles, motor-cars, dyes, pottery, clocks and watches, hosiery, lace, machinery, electrical goods, glass, hardware, instruments, gloves, iron and steel, brassware, picture mouldings, musical instruments, paint, paper, silks, stationery, toys, and woollen goods. Merely to name these things will show how great is the variety of articles, from foods and materials to highly finished articles, which Germany now successfully exports.

She is particularly successful in things which call for scientific treatment, such as dyes or musical instruments; and it may be added that she is as thorough in toy-making as in the perfecting of first-class pianofortes. It is a notable fact that German iron and steel exports are now running neck and neck with our own, and that they bid fair to surpass ours.

On the export side, we also do a great trade with Germany. The list of our exports to Germany is a long one, and mainly consists of a great variety of manufactured articles; we are not, of course, in a position to sell much in the way of materials except coal and china clay. We do, however, send a variety of imported materials to Germany.

Chief among our exports of British manufactures to the Fatherland may be mentioned rubber goods, cotton yarn and manufactures, hats, leather goods, linen yarn and manufactures, machinery (about two millions a year), metals, spirits, woollen and worsted yarn and manufactures.

Our next most important customer in Europe is France, with whom our trade amounted to £77,800,000 in 1910. Our imports from France are larger than the exports which she takes from us. This partly arises from the fact that we draw foods and liquors from her, including large quantities of butter, cheese, eggs, fish, fruit, margarine, meats, oils, poultry, spirits, sugar, vegetables, and last, but not least, wine. France also sends us a large variety of manufactured articles, amongst which silks, fine woollen cloths, motor-cars, and fancy goods, are chiefly prominent. Our exports to France are chiefly manufactures, including iron and steel, machinery, tools, leather goods, woollen and worsted goods, chemicals, etc.

After France comes Russia, with a total trade with the United Kingdom worth £64,800,000 in 1910. Our exports to Russia form the least part of this, however, for our imports from Russia in 1910 amounted to £43,600,000. Russia, indeed, is an invaluable supplier of foods and materials, and almost all our imports from her come under those heads. In 1910 our imports of corn, grain, flour, and meal from Russia were worth fully £17,000,000, in addition to £3,000,000 worth of butter, £3,300,000 worth of eggs, £2,200,000 worth of flax and tow, and over £10,000,000 worth of timber. Our exports to Russia, on the other hand, consist chiefly of manufactures.

Next in order of importance in Europe come Holland and Belgium, with each of whom we do about £37,000,000 worth of trade in a year. Each of these countries has a liberal tariff; and although they are so small, we export to each of them about as much as we do to the great empire of Russia. Holland has only six million people, while Russia has 160 million people, yet in 1910 our exports to Holland were worth £12,700,000, and our exports to Russia £500,000 less than this.

Next comes little Denmark, with whom we did an aggregate trade in 1910 of as much as £25,400,000. The greater part of this figure stands for our imports from Denmark, which are really remarkable in character. Here is an account of the chief of them:

OUR CHIEF IMPORTS FROM DENMARK IN 1910.

Butter	£10,200,000
Eggs	1,700,000
Bacon	6,300,000
	18,200,000
Other imports	1,300,000
Total	£19,500,000

The three items butter, eggs, and bacon amount, it will be seen, to over £18,000,000 out of our total exports from Denmark,

worth £19,500,000. Danish export trade is almost entirely concerned with dairy produce; and it is impossible to exaggerate the skill which the farmers of the tiny kingdom have applied to their work. They have proved how farming can be made to pay by scientific treatment. There is no question whatever that we possess in our own soil the means of producing every pound's worth of the dairy products which we buy from Denmark; and, given reasonable railway rates, British town populations are obviously nearer to British farmers than they are to Danish farmers. If, therefore, the British farmer is beaten by the Dane, it can only be because he deserves to be beaten, or because railway rates are against him; probably both factors enter into the result.

It may be remarked in passing, although we are not here concerned with the point, that both British agriculture and Danish agriculture work without tariffs, so that that point can have no bearing on the result one way or the other.

There is only one thing in which the British dairy-farmer holds his own, and that is in supplying fresh milk to our great town populations. Success in butter, cheese, or milk production obviously begins with the cow; and where a Danish farmer knows exactly what a cow yields him in profit, a British farmer is often quite unable to tell, from his muddled accounts or absence of accounts, whether a cow or a number of cows are yielding him profit or helping him to sell milk at a loss. Again, the Danes turn their "separated" milk—i.e., the milk deprived of its butter—into bacon; hence the big bacon figure in the above table. Another most important point remains to mention. It is that the Danish farmers co-operate in order to economise effort and to produce graded and standard articles which can be depended upon. Such, in brief, are the reasons why the little land of Denmark plays such a big hand in the British food market. The British farmer would do well to remember that he can play the same hand if he likes, for the cards in this game are not dealt by chance, but provided by science.

Our exports to Denmark were worth £5,400,000 in 1910. This means that Denmark is a very good market in proportion to her size.

Next in the list come Italy and Spain, with each of whom we do a trade worth about £20,000,000 per annum. Our trade with these two countries differs very greatly, however. Our exports to Italy are great, while our imports from Italy are comparatively small; this is because Italy is not a considerable exporter of such supplies as we need, while she is an increasingly large consumer of coal and goods. To Spain, on the other hand, our exports are worth less than £5,000,000, while our imports from the Iberian peninsula are worth nearly £14,000,000. There is a simple explanation of that. We draw from Spain an enormous quantity of iron-ore and considerable quantities of copper, lead, pyrites, quicksilver, and zinc. It is a condition of trade which, while useful to us, reflects very greatly upon Spanish development. Even when allowance is made for the fact that Spain has very little coal, the Spanish people have good cause to ponder whether they are doing all that might be done with their great mineral resources.

Next in order of importance come Switzerland, Austria-Hungary, and Norway. The most notable of these is Switzerland, with whom we do a trade which is very great when her small size is taken into account. Our trade with Austria-Hungary is very limited, in view of the fact that the dual monarchy has a population of about fifty millions. With regard to both Switzerland and Austria-Hungary—and, indeed, we might name every European nation in this regard—it is more than doubtful whether the British exporter takes as much trouble as he might do to push trade. Swiss official records enable us to test this point thoroughly. Switzerland publishes the number of foreign commercial travellers who visit her; and in the following table we show the chief sources of Swiss imports, and contrast them for each country with the number of commercial travellers sent to Switzerland:

PUSHING TRADE IN SWITZERLAND

Showing the number of commercial travellers sent and the goods sold in 1909.

Country Sending Travellers	Goods Sold in Switzerland	Number of Travellers Sent
	Francs	
Germany	538,000,000	4,711
France	318,000,000	1,531
Italy	204,000,000	1,405
Austria-Hungary ..	105,000,000	248
United Kingdom ..	91,000,000	61
Belgium	35,000,000	82
Holland	17,000,000	35
Total for above and all other countries	1,642,000,000	7,097

Surely these are facts of the greatest significance. Can we wonder that Germany heads the list of importers into Switzerland when she sends nearly five thousand commercial travellers into that country in a year? Her efforts, it will be seen, outdistance all competitors. Both France and Italy, however, send about 1500 commercial representatives each in a year, and each does a very big trade. The United Kingdom is content to send *sixty-one* travellers; and in view of this curious fact it is somewhat surprising that our trade with Switzerland is as large as it is. What is true of Switzerland we know to be true, although we have not such precise records, of the Austrian, German, Russian, Italian, and other great and small markets.

The remainder of our European trade need not detain us at any length, but details are given in the table for Portugal, Roumania, Bulgaria, Greece, and Turkey, leaving but a small fraction of the European markets without analysis.

The New World of the Americas next claims our attention. The list is naturally headed by that rich land the United States of America. We give her here her full title, because the title "United States" is the common possession of a number of the American Republics. Our trade with the United States is easily greater than that we do with any other country, but comparison of our dealings with Germany will show that this is mainly on the score of imports. The United States is not yet a very great exporter of manufactures in proportion to her capacity, and American competition in the British market is a comparatively small thing. Our dealings with the United States are chiefly concerned in obtaining from her an enormous quantity of food and raw materials. Thus, if we make a list of our imports from the United States of such categories as exceeded £250,000 in value in 1910, we get the result shown below.

This list accounts for the greater part of our imports from the United States, and it will be seen that food and materials form by far the greater part of it. The outstanding item is raw cotton, of which the United States has almost a monopoly of the world's supply. The other items over £1,000,000 are lard, leather, machinery, meat, copper, oils, skins, sugar, tobacco, timber, live animals, corn, fish, and fruit. It is true to say that but for these imports from the United States a great deal of the work of the United Kingdom could not be carried on. With regard to manufactured articles, we export to America more than she sends to us.

The American group of nations presents many other points of exceeding interest. Argentina, it will be seen, is second, and by no means a poor second, to the United States as a supplier and as a market; our trade with her in 1910 reached nearly fifty millions. Few people realise that amongst foreign nations Argentina ranks for importance in our trade only after the United States, Germany, France, and Russia, and that in 1910 we did more trade with Argentina than with Canada. The Argentine figures are likely to rise to very much higher levels; the progress of the Republic has been marvellously rapid of late years, whether measured by population, or production, or

OUR CHIEF IMPORTS FROM THE UNITED STATES IN 1910.

Article	£	Article	£
Lard	4,200,000	Rosin	501,000
Imitation lard	459,000	Skins and furs	1,594,000
Hops	418,000	Soap	349,000
Implements and tools	228,000	Starch	251,000
Instruments and scientific apparatus	782,000	Sugar	1,989,000
Leather	4,057,000	Tobacco (chiefly raw)	2,815,000
Machinery	2,287,000	Timber	3,388,000
Manures	288,000	Wood manufactures	849,000
Meat	8,917,000	Wool and woollen rugs	500,000
Copper (unwrought)	2,420,000	Raw cotton	48,800,000
Iron and steel	641,000	Live animals	2,598,000
Lead	428,000	Boots and shoes	510,00
Oils (chiefly petroleum)	5,280,000	Indiarubber	818,000
Oil-seed cake	470,000	Motor-cars	322,000
Oleo-margarine	425,000	Chemicals	430,000
Painters' colours	351,000	Grain and flour	10,455,000
Paper	275,000	Drugs	276,000
Paraffin-wax	872,000	Fish	1,021,000
		Fruit, fresh and preserved	1,519,000

external trade. In 1900 the population was 4,500,000; it was over 6,000,000 in 1910. In 1900 Argentine imports and exports were worth £53,000,000; in 1910 they were worth about £150,000,000, *an increase of about two hundred per cent. in only ten years.* Argentina now counts for much more in commerce than a great many European nations, including Norway, Sweden, Spain, Switzerland, and Portugal, and her trade is almost on a parity with that of Belgium, Italy, and Austria-Hungary.

The Great Growth of Commerce with Latin-America, Once Regarded as Unimportant

Brazil has also a very fine production and commerce, and our trade with her in 1910 was worth thirty-four millions. Chili comes next in importance amongst the Latin-American nations, our trade with her being worth eleven millions. These three nations, Argentina, Brazil, and Chili, are allied in a combination which has been dubbed the "A.B.C. League." Amongst the other American nations, we give figures in the table for Mexico, Peru, Uruguay, Bolivia, and Colombia, our trade with all of which is of growing importance. We have to realise that we are witnessing in some of these lands the evolution of Great Powers which in the time to come will count for far more in the world than many European nations of old and proud traditions. Until the last few years we have for the most part dismissed Latin-America as a collection of unimportant, ebullient, and troublesome communities. We forgot that Europe also has known such warfare, and that petty strife was a passing stage. Suddenly the world woke up to the fact that those people who had invested their money in South American securities were really in a better position than those who had put their faith in European gilt-edged stocks. At the present time, to give a few examples, Argentine 1886–7 Five per Cent. Bonds, Brazilian Five per Cent. Stock, and Chili 1896 Bonds are all at a premium, and some of the Argentine railway stocks are at a handsome premium, and can only be bought to yield about 4½ per cent. interest.

Why Should Not Mesopotamia Again Become the Home of Great Peoples?

The Asiatic group of countries next claims our attention. Curiously, we do with little Japan almost exactly the same amount of trade as with great China; the fifty million Japanese buy from us rather more than the four hundred million Chinese. This will not always be so. The next twenty years is likely to witness an enormous expansion of Chinese industry and commerce, but everything in this connection depends upon the establishment of a stable Government and of liberal institutions to set free the mighty energy of a people numbering from one-fourth to one-fifth of the world's entire population.

A fair amount of trade is transacted with Turkey-in-Asia, Persia, and the Philippines, and doubtless there are possibilities of development in these places in the future. Turkey-in-Asia certainly presents great possibilities, as we may realise by recalling what great nations once flourished in plains that are now desolate. There is every reason to believe that modern science could do more for Mesopotamia than the ancients who irrigated it and made it the fertile home of powerful peoples.

Our list of nations ends with the African group. The development of Egypt under British guidance has been magnificent, and British trade with her is now worth thirty millions a year. Egypt, thanks to the Nile, is the only great nation remaining in North Africa. We should not suppose, however, that the remainder of North Africa is incapable of development.

The Fluctuating Fight in Africa Between Man's Science and the Great Desert's Advance

Broadly speaking, what has been happening for centuries is that the desert has been beating uncivilised man, and without the aid of science the desert would conquer him utterly, and wipe him out of existence. As the French have shown in Algeria and Tunis, the desert can be beaten. Science will give back North Africa to the world, we may well be assured. With regard to other regions of Africa, the future may hold immense possibilities. Our newly acquired knowledge of the means of combating tropical diseases should assure the practicability of ample economic development by the white races of the vast and varied territories of what is still the Dark Continent.

Many and varied are the lands we have seen in our survey. The grand total of our commerce in merchandise—over twelve hundred millions sterling—is the aggregate of the transactions of one nation only with the rest of the world. Elements of competition, elements even of strife, enter into the vast business we have reviewed; nevertheless must commerce make for international amity by sinking the suspicion and distrust of strangers in the confidence and faith which grow, and can only grow, out of knowledge and mutual dealing.

COUNTRY.	U.K. Imports from	U.K. Exports of Imported Goods to	U.K. Exports of British Goods to	Total Trade of United Kingdom
	£	£	£	£
(1) BRITISH EMPIRE:				
Canada	25,600,000	3,000,000	19,600,000	48,200,000
Newfoundland	600,000	100,000	1,000,000	1,700,000
Australia	38,600,000	3,400,000	27,600,000	69,600,000
New Zealand	20,900,000	700,000	8,700,000	30,300,000
Cape Colony	7,700,000	800,000	8,000,000	16,500,000
Natal	2,100,000	400,000	5,100,000	7,600,000
Transvaal	500,000	500,000	5,800,000	6,800,000
Orange Colony	—	—	500,000	500,000
Rhodesia	100,000	100,000	800,000	1,000,000
India	42,800,000	1,000,000	46,000,000	89,800,000
Ceylon	6,000,000	100,000	2,300,000	8,400,000
Straits Settlements	11,600,000	100,000	4,100,000	15,800,000
Malay States	1,500,000	—	400,000	1,900,000
Hong Kong	600,000	200,000	3,600,000	4,400,000
British West Indies	2,300,000	500,000	2,400,000	5,200,000
British Guiana	800,000	100,000	600,000	1,500,000
Rest of the Empire	8,800,000	1,100,000	10,800,000	20,700,000
Total: British Empire—	170,500,000	12,100,000	147,300,000	329,900,000
(2) FOREIGN COUNTRIES:				
German Empire	61,800,000	17,900,000	37,000,000	116,700,000
France	44,300,000	11,000,000	22,500,000	77,800,000
Russia	43,600,000	9,000,000	12 200,000	64,800,000
Austria-Hungary	7,500,000	1,100,000	4,000,000	12,600,000
Italy	6,500,000	1,900,000	12,500,000	20,900,000
Holland	18,500,000	5,200,000	12,700,000	36,400,000
Belgium	19,200,000	6,900,000	10,900,000	37,000,000
Denmark	19,500,000	500,000	5,400,000	25,400,000
Spain	13,900,000	500,000	4,900,000	19,300,000
Norway	6,600,000	500,000	4,000,000	11,100,000
Sweden	11,800,000	1,100,000	6,700,000	19,600,000
Switzerland	9,800,000	500,000	3,400,000	13,700,000
Portugal	3,100,000	600,000	2,800,000	6,500,000
Roumania	3,200,000	100,000	1,800,000	5,100,000
Bulgaria	100,000	100,000	700,000	900,000
Greece	2,300,000	—	1,500,000	3,800,000
Turkey-in-Europe	1,300,000	100,000	3,500,000	4,900,000
United States	117,600,000	30,700,000	31,500,000	179,800,000
Mexico	2,300,000	200,000	2,400,000	4,900,000
Argentina	29,000,000	600,000	19,100,000	48,700,000
Brazil	17,500,000	400,000	16,400,000	34,300,000
Chile	5,200,000	300,000	5,500,000	11,000,000
Peru	3,700,000	100,000	1,300,000	5,100,000
Bolivia	1,400,000	—	200,000	1,600,000
Uruguay	1,700,000	100,000	2,900,000	4,700,000
Colombia	1,000,000	—	1,200,000	2,200,000
Cuba	2,700,000	600,000	1,900,000	5,200,000
Japan	4,300,000	300,000	10,100,000	14,700,000
China	5,500,000	100,000	9,200,000	14,800,000
Persia	500,000	—	700,000	1,200,000
Philippines	1,700,000	—	1,200,000	2,900,000
Turkey-in-Asia	3,200,000	100,000	5,100,000	8,400,000
Egypt	21,000,000	200,000	8,700,000	29,900,000
Morocco	600,000	200,000	900,000	1,700,000
Other Foreign Countries	15,900,000	800,000	18,300,000	35,000,000
Total: Foreign Nations—	507,800,000	91,700,000	283,100,000	882,600,000
Grand Total: All the World—	678,300,000	103,800,000	430,400,000	1,212,500,000

LAW, THE STEADYING FORCE OF SOCIETY

AN ARTIST'S CONCEPTION OF ROMAN LAW—THE BASIS OF THE JUDICIAL SYSTEMS OF TODAY

This painting, by Mr. Edwin H. Blashfield, in the Youngstown Court House, Ohio, is from a photograph by Mr. Peter Juley, by courtesy of Messrs. Owsley, Boncherche, and Owsley, architects.

PUBLIC OPINION—DICTATOR

Out of the Clash of Personal Wants and Interests Arise the Social Influences that Make for Order

THE SECRET OF STABILITY IN SOCIETY

NOWADAYS, to say that a thing is conventional is to condemn it. A convention is something which is not natural and spontaneous; and, this being the case, some persons lightly think that it always can easily be set aside. But, as a matter of fact, the practices at which mankind arrives by tacit consent and tradition, and without any definite machinery for enforcing them, are often splendid and vital products of conflicting social energies. They play a very important part in the evolution of human societies.

Looked at closely, nearly everything that we value and work with in the moral, intellectual, and artistic fields of social activity is conventional. Language, for instance, is the merest of conventions. Except, perhaps, for a few purely natural sounds of exclamation, the entire fabric of human speech is built up of strange, arbitrary symbols which are certainly neither natural nor spontaneous.

Without conventions we should become as natural as animals—a little higher than the ape, perhaps, and certainly much lower than the lowest savage. Such social forces of a primitive sort as still obtained among us would fail to produce any progress, because of the disconnected and wasted way in which they worked. It was the writers of the French revolutionary school in the eighteenth century who brought the term "conventional" into contempt. Their theory was that Nature had made man noble, enlightened, virtuous, and so on, and that civilisation had degraded him to his present sad condition. Sweep away all conventions, they said, and the golden age of humanity will return.

Their extraordinary and mischievous fallacy no longer obtains in full force. The noble savage is not now held up to general admiration by even the most philosophical of modern anarchists; and the date of the Golden Age of the simple life has been violently shifted, and placed, not in the dim past, but in the remote future. Perhaps when the earth is freezing beneath an extinguishing sun, the conventions of human society will gradually be destroyed—though it is doubtful if the anarchists of that period will enjoy their freedom from all conventionality.

The truth is that every convention is a reservoir of social force. In the absence of conventions there would be an extraordinary waste of power. A water-mill adds nothing to the volume and pressure of the stream by which it is built. But the stream, in spite of its strength, produced none of the effects that the mill produces. Its force was running to waste, but the mill saved and husbanded the power for the use of man. By means of the dam, the race, and the machinery of the mill, the current that flows into the millpond is charged with a new and special power.

In somewhat a similar way the reservoirs of social force transform a current of thought and feeling into a permanently useful source of energy. They serve the same purpose in regard to the spiritual fabric of society as material institutions do in regard to the material structure of society. A conventional element can indeed be traced in some parts of the framework of modern civilisation which seem at first glance to be as solid and real as the steel girders and beams of a railway bridge.

For instance, it is only by reason of a convention that coins of gold, silver, and copper, and pieces of paper on which symbols are written or printed, are accepted throughout the civilised world as the medium of exchange. Really unconventional persons should do their shopping

at the tail of a drove of cattle or a flock of sheep, with a few chickens and baskets of vegetables for use as small change.

In some cases, no doubt, a convention becomes a hindrance to the advance of civilisation. A current of more progressive force has been discovered, but is prevented from coming into general operation by reason of the power which some older convention exercises over the minds of the race. The conflict often occurs; it is indeed an important process in the evolution of human society. To talk, however, of abolishing some part of the social machinery because it is conventional is almost as silly as to talk of repealing a law because it is legal.

The Majority of People Still Governed by Their Primal Wants

In a previous chapter of this work we examined some of the larger formative forces of society, dealing with them one by one, and neglecting the interaction between them. This we did for the sake of clearness; but in actual life it is the interaction and conflict of forces that are important from the practical point of view. Each individual is sometimes inclined to work only in the interests of himself and of his group or class. Sometimes his aim is intensely and naturally selfish. In the general struggle for the means of livelihood, for example, there obtain all kinds of individual competition. Napoleon raised a laugh against his foes by saying that if you scratch a Russian you find a Tartar. But, as a matter of fact, if you scratch any man, you find a savage.

We have our primal animal wants. If they are not satisfied we are soon moved by primal animal passions. Only in so far as we are partly released from the daily task of life by a provision for primary material needs are we able to erect our heads and cultivate the finer things of civilisation. And with all our progress the larger number of persons in the world to-day are still governed by primal wants.

The Clash of Individual Interests Followed by Clash of Group Interests

Even rich nations remain only a span from immediate distress for the necessities of life. A general railway strike lasting a week or two would spread physical misery through millions of homes; an effective blockade of Great Britain by a hostile fleet would, in less than three months, bring out into full play all the hunger forces working quietly and regularly in our population.

The human passions, desires, and interests which form the energy of society are continually in conflict. When the primal wants of the individual are satisfied, new wants arise. When men are sure of their bread-and-butter, they begin to struggle among themselves for jam. New aims, new ambitions keep them in continual competition.

Then above the individual conflict there goes on the battle of the groups. Among savages there is the clash of clan against clan, tribe against tribe; in civilised communities the division and contest of groups usually follows the lines of differences in occupations. Indeed, at quite an early stage in social evolution there is a division of pursuits which produces a conflict of interests. The wants of races of hunters gravely interfere with the aims of races of farmers; and a farming nation gradually splits up into a variety of classes, each of which often has class interests that cannot be extended except by some kind of struggle.

There is thus a social energy continually surging through society in all directions. The interests of men often work at cross-purposes, and sometimes to no purpose, clashing against one another in a way that would end in common ruin if there were no means of harnessing their energies.

Conventional Ideas Preserve the Balance in the Midst of Fierce Social Strife

Human society is a theatre of intense activity, where competing and antagonistic agencies are fiercely contending for the mastery. The complete domination of any one of these forces would prevent social progress, but by their interaction they often make for social equilibrium. The equilibrium, of course, is seldom or never perfect; a perfect balance of the social energies would mean stagnation and slow, gentle, but thorough decay. There must, however, be some balance of all the vast and varied forces, before a human community acquires the stability necessary in any sort of organisation.

Hence the need of conventions and institutions. Institutions that have executive agencies to enforce their enactments are usually later in origin than the main fundamental conventions of society, which derive their force from public opinion. But it is now difficult to surmise in what manner the fundamental conventions originated. They were certainly not legal agreements, and it is doubtful if they were the conscious result of intellectual effort. Probably, like Topsy, they "just growed."

Take the first and most important of all conventions—language. Our own tongue, which is now spreading to the ends of the earth, is one of the latest conventions of the human mind. As now used, it is founded on a Midland dialect, which became a means of communication between the Angles of the north of England and the Saxons of the south. Purer in vocabulary than the northern dialect, and simpler in grammar than the southern speech, it developed into a convention which was fairly intelligible to the people of all parts of England. The Norman conquest, however, threw the Midland language again into the melting-pot; and for two hundred years there was a conflict with a French dialect which has been preserved in the Channel Islands.

The Early Strife of Tongues in England Between English and French Conventions

Two conventions strove for the mastery, drawing their strength from two warring divisions of society. The division, however, was bridged over by human need: speakers of French and speakers of English required to communicate with each other. Each made some concession, the peasant learning many French words, and the lord many English words. Working together they simplified still further the grammar of the Midland speech and enriched its vocabulary; and at last, about the middle of the fourteenth century, a standard modern language appeared. Through the artificial conglomerate of confused French and English provincialisms there came the living and breathing utterance of the "King's English."

Much in our language is now French in spirit, even where the words are made of Anglo-Saxon material. This is due to the action of one of the most powerful of social forces—the imitation of superiors by inferiors.

The Imitation of Superiors a Formative Power in History

John Trevisa, a writer of the fourteenth century, says that in his time "homely country fellows liked to appear to be gentle folk and took great pains to learn French, in order to be more thought of." As a matter of fact, it was not French they studied with such eagerness, but only the Norman dialect which had become the convention of the noble class; and when a farmer sent his boy to school it was chiefly with a view to learning this dialect.

Here, perhaps, we discover the explanation of a very curious phenomenon in other conventions besides speech. There have been since the New Stone Age few conquests in Europe in which the defeated race was utterly destroyed by the conquerors. For instance, Norman and Dane, Saxon and Briton, and Gael have swept over our country, which was once inhabited by scattered tribes of small, dark Iberians, yet the Iberians are still a chief part of our population. Indeed, they seem to be now increasing largely under the conditions of our urban and industrial civilisation; and many observers are inclined to think that they are more resistant to the selective agencies of city life than all the newer elements of our strangely mingled nation.

Yet the Iberians of Britain and Ireland have kept none of their original conventions. Conquered by the Celt, they adopted Celtic speech and customs; under Anglo-Saxon rule, they became practically Anglo-Saxons; and when the Danes and Normans arrived they followed their new masters. The fact is that even where a dominant race is few in numbers, as the Gaels seem to have been, the subject people often tends to assimilate its culture by imitation. Conventions are seldom propagated by main force; they spread from mind to mind, partly by suggestion, and partly by the prestige of a ruling caste or class.

Mrs. Grundy, the Social Conscience that all Laugh at, yet Obey

We need not turn to primitive races of ancient times to study the laws of convention. Our own Mrs. Grundy is a wonderful example of the influence of something which is earlier than law and morality and religion, forming in a way the source of all the later institutions of society. The only modern thing about Mrs. Grundy is her name. She is some hundreds of thousands of years old; and she appeared in the world when man became really man and learnt to communicate with his fellows by means of speech. She is the primitive form of the social conscience, careful of appearances rather than of realities. "What will the members of my group think of this action of mine?" That is the feeling for which Mrs. Grundy stood and still stands. No appeal was made to that individual sense of right and wrong which has to be moulded by religious institutions and confirmed by stern laws rigorously executed.

Even customs had hardly consolidated into a rule of life when Mrs. Grundy entered into the theatre of social activities, and began to restrain and regulate the conflict of individual passions and interests. We all laugh at Mrs. Grundy, and we all obey

her. To understand Mrs. Grundy, however, is a little more difficult than to laugh at her, but very profitable. Rightly understood, she helps us to see clearly into the foundations of the social process as it works in the individual.

Man is not a person who stands up in isolated majesty or meanness, passion or humility, and sees, hits, worships, or fights another man who does the opposite things to him. He cannot be considered a unit in the social process. On the contrary, a man is a social outcome rather than a social unit. His individuality is the smallest part of his make-up; he is always, to a large extent, also someone else. His social acts are his because they are first society's; otherwise he would not have learnt them, nor have had any tendency to do them. Everything that he learns is copied, reproduced, and assimilated from his fellows; and what all the members of his group do and think is thought and done because they have each been through the same course of copying, reproducing, and assimilating. When a man acts quite privately, it is always with a boomerang in his hand; every use he makes of his weapon leaves an indelible impression upon himself. He cannot help being part of the public, even when he ranges himself against his fellows.

The Dual Part Played by Man as soon as He Arrives at Social Consciousness

The things a man wants in life are the things which, by the very same thought, he must allow the others also the right to want. He cannot do otherwise. He is so largely a social product that he is bound to think socially. If he insists on the gratification of his own wants at the expense of the legitimate wants of others, of which he is aware, then he does violence to his sympathies and his social feelings. This in turn must impair his satisfaction. Perhaps it would be possible for a man to live an entirely and intensely self-regarding life, taking everything he could from the common fund of society, and giving nothing whatever back. In this case, however, he would lose more than he obtained; ceasing to be a social creature, he would cease to be a man. He would be more a madman than a criminal.

"What will others think of this action of mine?" is a question a man can himself answer. To put it paradoxically, he is "the others" as well as being himself. In different words, none of us escape from Mrs. Grundy, because each of us is she.

As soon as a common language, a common training, and a common occupation bound primitive men together in fairly large groups, the forces that make for convention began to control their individual wants and passions and interests. The law in regard to marrying outside the family may, as we have pointed out in an early part of this work, have been made in the pre-human stage of existence, but it was convention which gave even this primal law its overwhelming authority. And if we take the word in its largest sense, it is by convention that the entire machinery of society is worked.

Social Conventions that Cease to be Living Forces and Become Historic Curiosities

We have seen that the social conscience is in a way embodied in every individual; there is a public part of him which passes judgment on his private acts. This public part of him, moreover, passes judgment on the acts of his fellows, usually with more vehemence than in his own case. In his public capacity he is a convention-maker; and the decrees of society get their force, in the first instance, only through the working of the social conscience of the individual. Sometimes the conventions pass into established usages having the force of law; and when a society becomes more firmly organised, the usages may become legal enactments, and crystallise into institutions which have executive agencies to enforce their rules. But behind all these later developments of the social conscience there must still remain a living convention. If the convention lacks life and force, all the laws and institutions built upon it lose their efficacy, and are relegated to the museum of historic curiosities.

How Social Conventions may Fall into Disrepute, but are Naturally Upheld

Conventions expire in several ways: sometimes they are forcibly destroyed by rebellion, sometimes they are gradually outgrown, and sometimes they are altered by intercourse with other races and communities. If a large proportion of the young of any generation are born to rebel against the conventions of their group, or if they possess strains of heredity which make it impossible for them to agree with the demands of conformity, the society to which they belong must go to pieces, unless it has some means, apart from the appeal to individuals, for the enforcement of those social prescriptions on which its organisation depends.

But in a stable community there must always be a fairly large number of average persons in whose mature opinions are

reflected the conventions, usages, sympathies, and traditions of the race. In their public capacity these individuals maintain the social level, and society finds in them a court of appeal. They are, in fact, a natural jury. They represent the average spirit of their age, standing in advance of the rebel and behind the reformer. In matters of politics they may be any shade of opinion, but in social affairs they are the conservators. They uphold the conventions purely as conventions, faithfully carrying on the generalised experiences of the race, and resisting all innovations of large scope.

The Danger of the Lover of what Has Been Losing All Originality

Naturally, they make little changes of detail in many of the traditions of which they are the vehicle. No individual's experience can fit exactly into a conventional mould; he is bound to originate to some extent. But, speaking in a general way, the social conservator lives so happily under the rule of convention that he is apt to condemn all originality of view and all originality of action. In periods of social rebellion he is a sane, effective, and steadying force. In periods of social progress he is an obstacle which cannot be removed, and yet must be surmounted.

To destroy him is to destroy the foundations upon which it is desired to build. He is the natural conservator of society and the repository of social prescriptions. Propagate a new convention and make it a rule of the social conscience, and he will become its administrator. In a way, he is an organiser, with all the virtues and defects of the man who deals admirably with things as they are; and the reformer is an inventor with a keen but narrow vision, bent on achieving one new thing and somewhat disregardful of the general scheme of social life.

The Rival Dangers of Social Inertia and of a Constant Ferment of Change

Without the reformer, the conventions of society would end in social inertia; without the conservator, there would be a continual ferment of change with no lasting results. In ancient times the tendency was for societies to grow too conventional. As is well known, in nearly all savage races the individual has less freedom of action and less scope for initiative than persons have in highly civilised communities. Far from being a free man, as the revolutionary thinkers of the eighteenth century supposed, the savage is imprisoned in a narrow circle of conventions, customs, and wildly superstitious practices. Nothing except defeat at the hands of a race with a superior culture can enable him to break away from his traditions and assimilate new elements of social life.

On the other hand, the victorious race often suffers from the effects of its conquest. Settling as a dominant caste in a newly won territory, it preserves its conventions as a mark of distinction, and allows them to fossilise. The Aryans of India are an example of this strange racial conservatism. Surrounded first by the low aborigines, and afterwards hemmed in by new races of invaders, they became merely the copyists of their forefathers, and ceased to develop their social institutions. In the United States of America, on the other hand, a race of colonisers has, through various causes, become somewhat too unconventional. Their faculty of individual initiative has been marvellously stimulated by the pioneer work of developing the natural resources of a continent with the quick and powerful instruments of modern civilisation. The result is that, from a social point of view, they have become somewhat too adaptable.

The Over-Stimulated American People a Whirlpool of Wasted Force

They are too ready to run into the mould of the moment; they pulsate with social energy, but this energy never collects into permanent reservoirs of power. When viewed from a distance, the American scene appears to be a whirlpool of wasted force, as enormous and sublime as a spectacle as Niagra, but put to little or no lasting social use. Never in the history of the world was there such scope for the individual, but the individual flourishes, and the race decays.

In China, on the contrary, where for thousands of years conventions have had a peculiar force, the individual has been sacrificed to the race, but the race has become the most wonderful in the world. Its conventional framework is so strong that all which is of permanent value in the life of the Western world can be built into it. When this has been done the Chinese people will benefit by the strangely rigid organisation of their society. Very likely they will outbreed the white race, and certainly they will exert an influence on the social life of the whole world. The social problem of modern times is to combine conservatism and progressiveness—to retain all structural conventions while replacing those social prescriptions that have lost their efficacy.

PITIFUL CHILD-LIFE IN OUR CITIES

CITIZENS OF THE FUTURE WHO ARE UNANSWERABLE PROOFS OF AN URGENT NEED FOR SUCH USE OF EUGENICS AS WILL BRING TO THEM HEALTH AND HOPE

THE SCHOOLCHILD'S HEALTH

How Disease is Sown and Grown in Childhood, then Lamented, but only Thinly Weeded Out.

THE CHEAPNESS OF A SOUND START

We may look upon the school age in this country as approximately corresponding to the second septennium of life. This period of development, from seven to fourteen, is not arbitrarily limited, but has a definite physiological meaning. It begins at the conclusion of the period of brain construction, and ends at puberty, when the boy begins to become a man and the girl a woman. The Eugenist would therefore require to deal specially with the nurture of this period, even if it did not fairly coincide with the very definite mode of life which is imposed by our system of national education.

In dealing with the home-child, we saw that the nutrition rather than the instruction of the brain should be our primary concern. If we take care of nutrition, there is the more chance that we shall have a brain worth instructing afterwards. As regards the school-child, though the possibility and utility of instruction may now be admitted, nutrition and the maintenance of the proper conditions for development must still take the first place. But this is a new idea in national education; and the recent history of its arrival and results is so profoundly instructive that it must be detailed at some length.

The State saw long ago that it would be worth while to teach reading, writing, and arithmetic to all children. We have now had forty years of national education, latterly free, which has always been dominated by the simple idea that education is a matter of the intellect, and that what comes to school is a young, disembodied intelligence, waiting to be instructed. The teachers themselves have known better. It has been clear to them that what comes to school is a child, of which the intelligence is only one of the parts. They have known that their labour has been too often thrown away, because children came to school starved, or because they could not see the blackboard, or were half-deaf and could not hear, or because the children were simply incapable of learning. On this last point we shall dwell no further now, for the really defective child is a special problem, which no application of good nurture can solve. Such children are being dealt with in special schools; and the discussion of their needs really comes under the later heading of Negative Eugenics.

But as regards the other defects of the nation's school-children, physical defects, grave or slight, the voice of those who had to deal with the problem at first hand was ignored. National attention was directed to the subject in an extraordinary fashion, now to be described.

In the course of recruiting for the Boer War, the medical officers found that they were compelled to reject an enormous proportion of candidates on account of their physical defects. Many had bad teeth, many had early tuberculosis of the lungs, others had discharging ears, weak hearts, swollen glands in the neck, and so forth. Very notably, also, the recruits failed to come up to the required standard in the matter of height, weight, and chest measurement. So serious and unexpected were the facts revealed by the special circumstances of the Boer War that certain distinguished soldiers drew attention to them, notably the late Sir Frederick Maurice. It was obviously a serious matter that recruits had to be rejected in such numbers; and it did not seem exactly satisfactory to compensate by lowering the standard for admission to the army, though in some respects that had to be done.

The very natural idea of those who have not studied physiology is that bodily development depends upon exercise. "Physical training" is their panacea, which

would undoubtedly be justified if the evils it was called upon to meet depended upon lack of physical training. In such a case, to supply physical training would be truly scientific and effective, for it would be to "remove the cause" of the defect. More especially, as we can understand, are physical training and drill the natural resorts of the soldier in trying to improve the condition of recruits. He sees for himself that drill and regular work have useful results, notably in the carriage of the body; and he also observes the development of the chest which follows certain kinds of exercises, and thinks that useful, too, though the method of chest development employed in our army until the last few years was indeed injurious to the heart and lungs, because it promoted an artifical expansion of the chest that looked well, but interfered with its vital movements.

At any rate, the remedy for the state of our recruits, suggested by the influential soldiers, was physical training, even though no one could well suppose that physical training would restore the lost teeth, on account of which such a large proportion of rejections were required, to name no other illustration of the extraordinary fallacy of this reasoning.

An Inquiry Into the Physical State of Children After Thirty Years' Forgetfulness

Nevertheless a Royal Commission on Physical Training was appointed, with scope to study the facts in Scotland. That Commission set very effectively to work, surveying all the provision for physical training and drill that Scotland could boast. In the course of its inquiries the Commission thought that it might be worth while to gain some impression of the physical condition of Scottish school-children, such as were likely to come under any system of physical training that might be proposed. Accordingly, Dr. Leslie Mackenzie, now the Medical Member of the Local Government Board for Scotland, was asked to make a systematic inquiry into the facts of some school chosen for the purpose, which he accordingly did, this being the first occasion, more than thirty years after the establishment of national education, on which such an inquiry had been made. This is one of the many quite incredible facts of our national practice which are nevertheless true.

The first school chosen for observation was one situated in the most terrible slum district of Edinburgh, called the North Canongate. So terrible were the facts that subsequently a more detailed inquiry into the families as well as the scholars was made, and this inquiry was unluckily chosen by Professor Karl Pearson for his study of parental alcoholism, which required detailed observations of a "typical working-class population." Unknowingly he chose what is indeed the most celebrated and tragic instance of a debased slum population in our Empire. The results of his inquiry may be imagined. But meanwhile the first investigation had yielded valuable fruit. Only the few, social workers and doctors, including the present writer, who worked in this very population for some years, had any idea of the facts which Dr. Leslie Mackenzie's inquiry revealed.

The Alarming State of Physical Deterioration Officially Discovered in all Large Cities

The Committee naturally asked for further facts, and other schools were examined in Edinburgh, showing results not nearly so bad as those of the Canongate population, but quite bad enough. Other Scottish and then English cities were examined; and it was found that Edinburgh, as a whole, was no exception, but that a disastrous state of things existed throughout our child population generally.

Two vastly important results followed from this discovery. The first was the appointment of the Departmental Committee on Physical Deterioration, for plainly mere physical training was not going to meet the need, and the facts ascertained by the Royal Commission demanded further inquiry. The Physical Deterioration Committee met and issued a report which clearly demonstrated that the assertions made by the few who had been called "alarmists" were entirely justified by the facts. The Committee reported that physical deterioration was widespread, that the need was grave and urgent, and that public opinion required instruction on the subject.

The Arrival of the School Doctor Brings Hope to the School-Child

All this was great gain. The pioneer Eugenists found themselves supported by the authoritative official voice, the Press gave wide notice to the facts, and such bodies were formed as the National League for Physical Education and Improvement. These effects, be it observed, flowed from the Boer War, and the military demand thereafter for physical training of future recruits.

A second consequence was of far greater importance, for its effects are lasting, and will yet produce more effects. The evidence gained by the Physical Deterioration

Committee showed the need for more knowledge. The anthropologists in this country joined with the medical and philanthropic voices, saying how desirable it was that there should be a regular national stocktaking, not merely for immediate practical purposes, but also because of the value of such data for the students of the science of man. The demand began to grow louder and louder that we should have regular medical inspection of our schools. The present writer was one of those who made this demand, but he repeatedly coupled it with the prediction that medical treatment would have to follow upon medical inspection, and that we must face the cost involved. In this apparently reasonable prediction he was entirely wrong, as we shall see. Medical inspection was established, at any rate, and the doctor entered the nation's schools, never to leave them.

The Government's Discovery that the Children Have Bodies as Well as Minds

The Board of Education appointed a medical officer to deal with this entirely novel situation provided by its staggering discovery that school-children have bodies, a perplexing complication which had hitherto escaped its attention. Thus, after a generation, and as the fruit of a military campaign on the other side of the equator, the Board of Education gained the assistance of a medical man and his staff. That medical man is now Sir George Newman, Chief Medical Officer to the Board of Education, whose annual reports on the subject of his work are among the few most important documents now printed in this country.

It may practically be said that medical inspection of schools and scholars is now in full swing. It has afforded, as was to be expected, a mass of detailed and comprehensive evidence regarding the six million school-children in England and Wales, such as we never possessed before, and such as no nation can afford to be without. Similar work is, of course, being done in Scotland, with similar results.

The School-Children's Health the Foundation of the Health of the Whole Nation

Here we shall conveniently confine ourselves to Sir George Newman's recent Report for 1910, and shall take into account the comparison between that Report and its predecessor for 1909. We require to know not only what are the facts, but what is their trend, and how they are being modified, if at all.

What, then, are the bare facts of these six million children, the survivors of whom will be the great bulk of the nation's citizens and workers and young parents during, say, the next two decades? Obviously their health and physical condition lie at the foundation of the health of the adult population. As the Report reminds us, the conditions of life, both in respect of personal hygiene and of environment in general, which result in a high mortality under one year of age, lead on to a high degree of sickness and disablement among children of school-age. This, of course, is one of the most important facts of infant mortality, asserted by some few of us for a decade, and exhaustively proved by Dr. Newsholme in his recent comparison of infant and child mortality in different areas of the country. But just in the same way, and probably in still greater degree, the sickness of children leads to disease and disablement among adolescents and adults. Every step, therefore, in the direction of making and keeping the children healthy is a step towards diminishing the prevalence and lightening the burden of disease for the adult; and a relatively small rise in the standard of child-health may represent a proportionately large gain in the physical health, capacity, and energy of the people as a whole.

A Good Beginning in a Few Cases and Much Shirking on the Whole

We shall see in the sequel the large, practical, financial, and exceedingly topical moral of these official assertions. We are further reminded that many of the diseases and physical disabilities of the adolescent and the adult spring directly out of the ailments of childhood. Malnutrition, "debility," dental decay, adenoids, and measles in childhood are the ancestry of tuberculosis in the adult. They predispose to disease, and are, in a sense, both its seed and soil; and hence tuberculosis in the adult, which may be taken as a type and example of preventable disease, is in large part the direct development of disease in the child. The problem both of preventing and of treating the defects of children which are discoverable by medical inspection thus assumes an importance both more extensive and more serious than that of curing the individual child.

If such a huge problem is to be dealt with, if even its factors are to be ascertained, much putting of heads and hands together is required. Let us do justice to the faithful workers hitherto before we make our indictment. There are six evident branches of the school medical service, all necessary,

and all now in process, in a few cases, of being unified under school medical officers. These are medical inspection, medical treatment, the sanitation of schools, the provision and management of schools for the defective, physical training—not everything, be it observed!—and the feeding of school children. Meanwhile, the present facts of the children's physical condition remain; those facts are not ameliorated in 1910, as compared with 1909; and what has been done by a few local authorities—all honour to them—and the slight improvement in cleanliness, are as nothing compared with the huge bulk of the facts and their notorious shirking as a whole.

Statistics that Should Rack the Hearts of All Patriotic Citizens

Of the six million children on the school-registers of England and Wales, about ten per cent. suffer from a serious defect in vision—i.e., about six hundred thousand. Serious though these defects be, and gravely interfering with education, and endangering the nervous and mental health of the children, here is a state of things which, in the vast majority of cases, suitable spectacles can relieve. It seems somewhat unreasonable, and even wasteful, to pay for the skill and time required to examine these children's eyes and discover the defect, if somebody, somehow, is not going to be made to provide the cheap, simple, and effective remedy which is all that is required in most cases. But we must forbear further comment, for this is a trifling matter relatively—these six hundred thousand children with a serious defect in vision.

From three to five per cent. are more or less deaf. Here is a disability much underrated by those of us who are not deaf. To say the least of it, however, this is something which must rather militate against effective instruction in class, and must be often prejudicial to the worker's efficiency in later years. It is here asserted that, if proper care were taken of what we have called the "home-child," and especially if such maladies as measles were more seriously regarded and faithfully treated, very few children would reach the school-age already handicapped for school and for life as these hundreds of thousands of children are.

The Terrible Toll of Childish Suffering that Ought to be Stopped

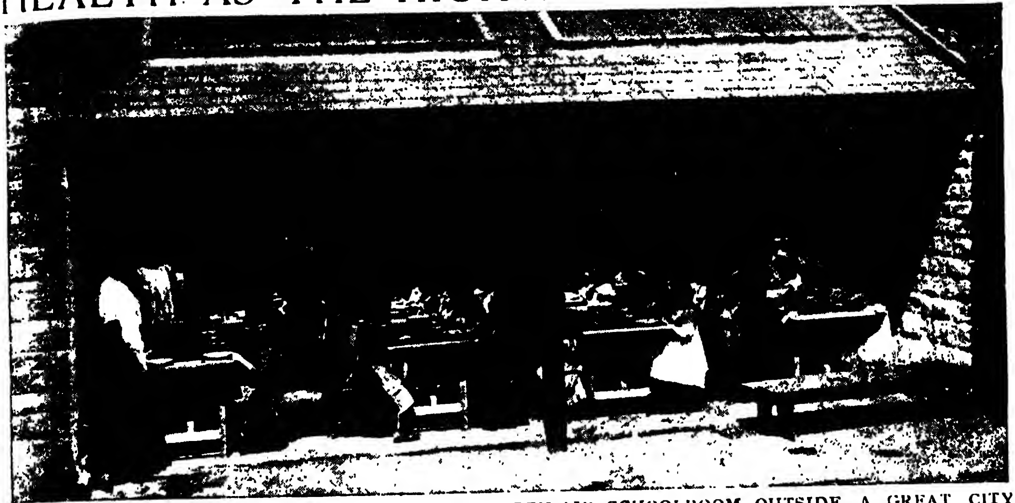
One to three per cent of our school-children are not merely deaf, but have suppurating ears. Here, again, is the direct fruit of the neglect of measles and scarlet fever in earlier years, combined with that malnutrition which, as we shall see, is so widespread, and which so greatly predisposes to such sequels of these common infections. This condition of the ears is further dangerous to the brain itself, and it is eminently amenable to surgical treatment.

About eight per cent of all these children have adenoids or enlarged tonsils of sufficient degree to obstruct the nose or throat, and thus to require surgical treatment. That is to say, there are now, we may safely assume, not less than half a million school-children, in England and Wales alone, who suffer from a condition of the throat which can be safely and finally cured by surgical operation in, say, a minute and a half. This defect has been partly studied elsewhere in this work, in connection with the problems of individual health. It is in childhood that it is most serious, for it interferes not merely with breathing or hearing, but also with general nutrition, partly by reducing oxygen supply to the developing organism, and partly by poisoning due to the microbes which always batten upon adenoids. Further, such children are specially liable to colds and sore throats, which interfere with their own education and which they spread in school. Lastly, Sir George Newman's suggestion that adenoids and large tonsils may predispose to tuberculosis expresses the best expert opinion of the day.

How Childish Ailments Neglected Prepare the Way for the Scourge of Consumption

A large and encyclopædic volume on tuberculosis, of international authorship and the most recent authority, has just afforded students a startling measure of evidence to show that the infection of the lungs in consumption occurs through the area covered by adenoids and the tonsils, and is immensely favoured by their presence. The microbes are inhaled, but not into the lungs. They are habitually arrested in the throat; and the local condition of the throat may be the crucial matter for the person in question, deciding whether the microbes are there destroyed, or are welcomed and allowed to pass through the well-known vessels which run from the throat to the lungs. The significance of adenoids has been vastly increased by these new observations, which only demonstrate what many students have asserted for years past; and it should scarcely be necessary to point out the national significance of the existence of half a million of these highly infectible children in our schools, ready to replace the half-million consumptives whom we have among us at

HEALTH AS THE HIGHWAY TO EDUCATION

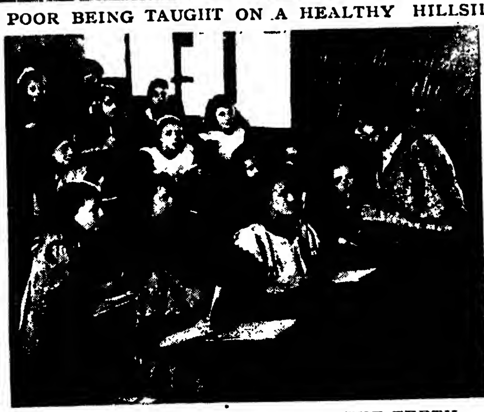


FEEDING DELICATE SCHOOL CHILDREN IN AN OPEN-AIR SCHOOLROOM OUTSIDE A GREAT CITY

AN EXPERIMENT IN EDUCATION—A SCHOOL CLASS AT WORK IN THE OPEN AIR

WEAKLY CHILDREN OF THE POOR BEING TAUGHT ON A HEALTHY HILLSIDE BEYOND THE CITY

THE SCHOOL EAR-DOCTOR



A LESSON ON THE CARE OF THE TEETH

THE SHOWER-BATH

The three upper pictures and that of the shower-bath are by courtesy of Dr. Ralph Williams, Chief School Medical Officer of Sheffield.

any time, and whose disease the nation is proposing to exterminate. The evidence of the experts suggests that we may spend vast sums of money in vain at later ages if we cannot be troubled to remedy this most easily remediable and most risky condition which is present in one school-child out of every dozen throughout the land.

The horrible and scandalous character of the present facts may in some degree be palliated when we consider the expense and difficulty of dealing with many forms of child-sickness. Thus, for instance, we have one to two per cent. of children who suffer from heart disease, a pathetic fact of which no more need here be said; and we have ten per cent who suffer from obvious and gross malnutrition, of which much more must be said. These are unmanageable or difficult problems. But the radical cure of adenoids and enlarged tonsils is a trifle. It would cost the nation a negligible sum to have every child in the schools cured within the next week; and the subsequent saving, to speak of money alone, to a nation which is going to spend whatever may be required for tuberculosis, would be incalculable. In some evident ways, therefore, we may single out this neglect of our children's throats as perhaps the least excusable and the most monstrous of all, as well as the most stupid and expensive.

Uncleanliness Distasteful but Less Specifically Injurious than Many Other Evils

Questions of dirt, merely, may almost be ignored in the present statement. It is true that some thirty to forty per cent. of the children have unclean heads or bodies, a deplorable proportion, which greatly complicates the problem of the good mothers who keep clean the children that *are* kept clean. Here is a defect which is well worth remedy, and which teaches us a good deal as to the inherent quality of parents, and the folly of supposing that this problem is only an economic one. But the Eugenist cannot pause over this, for he knows that unclean heads and bodies in childhood are practically negligible as regards future health and development, thus forming a very striking contrast to the condition we have just discussed, or that which is to follow.

For even more numerous than the children whose skins or scalps are dirty are those who have dirty mouths, associated with extensive and injurious decay of the teeth. The proportion of such children is not less than forty per cent.; and we are to realise that this figure refers only to really disastrous cases of dental decay. We are not here speaking of children who have lost a tooth or two, or who need a couple of visits to the dentist, and an occasional visit for inspection thereafter. The calamitous loss or destruction of irreplaceable teeth is alone included in this huge proportion. These children, unlike those whose uncleanliness is only external, suffer seriously. Mastication, and therefore digestion, is interfered with. There is chronic absorption of poisons from the dirty mouth, for every mouth which contains decayed and untreated teeth is a breeding-ground for offensive microbes, as the tongue, the breath, the digestion, and the state of the blood readily demonstrate to the doctor.

The Choice of Diet in Relation to Dental Decay in Childhood

This condition of the teeth of our children has early been recognised, because in the rejection of recruits, whence sprang these revelations, dental defect was always pre-eminent, and it was naturally looked for among the children. This is probably an increasing evil, fundamentally dependent upon improper diet, partly before the school-age, but probably in greatest degree during the period when the secondary teeth—ironically called "permanent" by anatomists—are emerging from the gums, and thereafter. In some degree the diet is of wrong composition from the point of view of tooth formation. But probably the consistence of the food is its most serious defect, involving little good, healthy need for chewing, which strengthens the teeth, increases the supply of blood to their roots, and mechanically cleanses them. The toothbrush, modern man's substitute for the dentifrice-diet of his ancestors, is almost unknown among our school-children; and they are allowed to go to sleep, too often, with the necks of their young teeth in the deadly embrace of chocolate or soft biscuit, which fatally promotes decay.

The Dangers of Allowing Poisonous Teeth to Remain Rooted in the Mouth

Dental decay is a disease chiefly of childhood and youth. For reasons still unknown, its incidence vastly diminishes after this period. The problem is thus to save as many teeth as possible from the dangers of this period of life. Then, as thousands of readers will know from their own experience, the remainder may much more easily be retained for many years. Whatever the factors of causation, and however difficult their control, it is certain that we cannot afford to allow our school-

children to have decaying teeth in their mouths. If the teeth cannot be saved they should be removed, because of the absorption of poisons which their presence involves, and the risk of tuberculous infection, and because of the risk which sound teeth run from the propinquity of decayed ones. Teeth habitually infect one another, so that to extract one may often be to save its neighbour or neighbours.

It is reckoned, however, that at the present time there are not enough dentists in the country to deal with the needs of the children in the nation's schools as those of more well-to-do children are dealt with. There are not even enough dental resources for the extraction of unsavable teeth. All this must be changed if we are to do the absolutely necessary work in our children's mouths in the future, especially as it is very doubtful whether, for a long time to come, we shall be able much to diminish the number of mouths needing skilled treatment.

The one per cent. of ringworm among the children is of no moment from the eugenic point of view. The same proportion of readily recognisable tuberculosis is only too important.

The Tragedy of Tuberculosis as It is Started Before and in School Life

This figure, as we know from positive evidence, gives no indication of the real prevalence of the disease among the children. In order to ascertain the presence of tuberculosis it is necessary to apply delicate tests such as are quite out of the question in medical inspection at the present time. We are gradually learning that tuberculosis is primarily a disease of childhood, and that the whole problem will ultimately be found to centre in the child. Meanwhile we have at least sixty thousand gross cases of tuberculosis in the schools; and the one certainty about them is that they should *not* be in the schools. This whole problem of tuberculous school-children, and infection at this time of life, leading up to the existence of tuberculosis in the community at all later ages, is too large a one to be dealt with effectively even by the ideal school medical service of the future. It is, for instance, involved with the question of the milk supply, and can never be satisfactorily settled until that is. Nevertheless, we note the existence of this disease already at the school-age, and in far larger proportion than the crude figures of ordinary medical inspection can indicate. The moral may be found when we realise the problem of the insurable population at the age of sixteen.

Finally, and doubtless most important of all, a large proportion of the children are suffering from serious malnutrition. The percentage cannot be less than eleven or twelve, to allow nothing for grades of malnutrition which show their presence in ways too subtle for ordinary observation—perhaps only in the quality of the work done by the child. Beyond all question, this fact of malnutrition can never be remedied by the school medical service, because it depends, in the great majority of cases, upon prolonged error, chiefly in diet, before ever the child reaches school at all.

The Question of National Efficiency Begins With the Mother of the Home-Child

The writer wishes especially to insist that these most recent figures of malnutrition, with all that it means, entirely support his view that we must begin at the beginning, and care for the expectant mother, the infant, and the home-child as we have never done hitherto. The school-age has responsibilities enough of its own, and it can never remedy damage already done by neglect in the earliest years of life, so habitually forgotten hitherto. The demand is here made, in this connection, for detailed inquiry into the condition of all the children when they enter school, and for analysis of the facts, so as to determine how far the school can ever expect to deal with the problems which arise within it, when new problems daily enter it.

Meanwhile, let us quote Sir George Newman's verdict on the formidable total of disease and defect which we have here reviewed—that it "means a serious amount of suffering, incapacity, and inefficiency, which at least must greatly limit the opportunity and diminish the capacity of the child to receive and profit by the education which the State provides, and must involve a continual increase in the national burden of sickness and disablement."

The Ignorant and Expensive Economy that Forgets What the Ultimate Cost Will Be

Thus the prediction that medical treatment was necessarily involved in medical inspection, and that we must face the cost involved, has been proved untrue. Or, rather, we have faced the cost involved, and have turned away. The methods adopted are mainly three: either we have said it was not our business, and have left it alone; or we have made arrangements with the hospitals to receive school-children as out-patients and deal with them; or, in

a very few cases, not half a dozen, we have followed the example of the Germans, and established school-clinics. The adoption of the first and second courses, overwhelmingly condemned by common sense and experience and economy, as against the third, which has everything to commend it, has been dictated by the ignorant and expensive economy which forgets what these children will cost the State later.

No one will be able to forget it now; and that is why this whole problem is on the verge of a new epoch. All the foregoing observations will be weighed and realised when National Insurance is set in motion, and every young worker of sixteen comes under its provisions.

Health-Insurance by the State Means Beginning at the Beginning

No magic is at work between the school-leaving age and the insurance age two or three years later. The children whose condition has been described will then be the workers. We may decline to pay for them at the school-age, but we shall have to pay for them at the insurance-age. All the present estimates of the cost of insurance are understated; all require restatement in the light of the foregoing facts regarding the very persons who, in a year or two, with their tuberculosis and adenoids, and heart disease and suppurating ears, and bad teeth and dyspepsia, and so forth, will be applying for the sickness and medical and sanatorium benefits of the Act. The notion that the youngest people involved in the scheme will cost it little is simply a myth, and medical inspection of school-children exposes it.

The obvious consequence will be that public opinion will demand what the very few have hitherto been demanding of the public. If national insurance is to be economically feasible, if it is to start with sound bodies at sixteen, as it should, and then provide for keeping them sound, we must take our school-children in hand.

The Public Will Adopt School-Treatment not Because of Science but for Economy

The treatment of school-children *will* follow medical inspection, after all, but not, as some of us supposed, by force of any appeal to the public head or the public heart, but by the overwhelming argument addressed to the public pocket—much the most sensitive organ of the three. And the Eugenist who has hammered for years at this question may further predict that if national insurance, for twenty years to come, is not to be an almost intolerable burden, we must begin with the school-child, and the home-child also, at once—sooner would not be soon enough.

One important question remains. Within a few months it will have to be faced by local authorities all over the country. How is the work to be done? On this the answer of those who have tried, here and abroad, is unanimous. To make arrangements with private practioners, or, worse, with the out-patient departments of hospitals, as we still do in London, with the most disastrous consequences, is a tragic farce. As Sir George Newman shows in his last Report, the child can only be dealt with by co-ordinated effort, "for securing that all the forces necessary for the effective treatment of the child are, in fact, concentrated upon his condition. The failure in the past to secure continuous and effective treatment of a character calculated to lead to permanent cure has been due not to any lack in number or skill of the medical men available, but to the fact that, whether in their capacity as private practitioners in the home, or as members of the staff of a voluntary hospital or dispensary, or as officers of an authority, they have been acting as isolated agents, each unco-ordinated with the other, though all are equally necessary contributors to the radical and ultimate cure of the child."

The Establishment of School Clinics a Necessity of the National Well-Being

Only the school clinic, the centre of a School Medical Service, can supply the need, which involves the care and treatment of the child at home as well as at school. We shall ere long have such clinics in official association with every school in the land. For country districts there will have to be travelling clinics; the dental clinic will be a subordinate but essential part of the service. The six departments of work, already detailed, will be welded and unified, meals will be given to children who need them, but the home and the parents will be treated as well, as they require, and the fundamental question of the nutrition of the children will be placed upon a proper basis.

This having been done, forty years after the beginning of national education, and the teachers being provided with children who can breathe and see and hear, national education may at last be possible. It will then be our duty to deal with the next subject in rational order—the education of the nation's children as tripartite unities of body, mind, and soul.

A FIGHT FOR THE MASTERY OF THE AIR

A CONCEPTION OF A BATTLE TO THE DEATH BETWEEN AN AEROPLANE AND AN AIRSHIP

THE FORMING OF WORLDS

Guesses as to How the Solar System May Have Clashed, Fused, Divided, and be Cooling into Lethargy

WHAT STAR-GAZING UP TO DATE SHOWS

We have seen that, notwithstanding the abandonment of Laplace's original theory, we have reason to believe that a nebula of some kind was the first stage in the history of the solar system. Just so is a single cell the first stage in the history of such an individual as ourselves; but we are inclined to ask its origin, and find it twofold, for it was formed by the union of two cells, derived from two parents. Similarly the single nebula which was the first stage of the solar system was probably a double object in reality, of double origin, like a fertilised germ-cell or zygote. The solar nebula was a "zygote" also, formed by the yoking of two bodies. Those bodies may well have been two dark suns, such as we believe our own sun destined to become. If such bodies met, they might well form a nebula. And we have argued that from such a nebula all the solar system, including the meteorites, might have been evolved. But there is an alternative, and we should note it.

Continually to harp upon such small and apparently insignificant bodies as the meteorites may seem absurd; but we have already seen that there is a theory of the solar system which traces it to the aggregation of meteorites, and we have not yet heard the last of this "meteoritic hypothesis" of Sir Norman Lockyer, some form of which we may yet find necessary to complete our nebular hypothesis. The supposed opposition, or alternative, between the two may be unreal. We have argued that the collision between two dark suns might produce a nebula. But it is not necessary to believe that all the matter of those two bodies would become gaseous or nebulous, any more than it is necessary to assume that they met strictly end-on, as when a billiard-ball strikes another "full." Thus it is quite possible that parts of these bodies might have escaped inclusion in the nebula, and might remain to record somewhat of the past for us.

Now it may be that the meteorites, or some of them, have really had this history. It will be enough for the present if we note that meteorites are palpably fragments of a once larger mass. Their shapes and composition show beyond a doubt that such is their all-significant origin. On chemical and "geological" analysis they are found to contain elements familiar upon the earth, but these elements are combined into minerals which show no resemblance, either in themselves or in the manner in which they are held together, to any portions of the earth that we know. Thus their study is not ordinary geology, for they are not of earthly origin at all.

Further, many of them contain remarkable quantities of such gases as hydrogen, so as to suggest that they must have been formed under great pressure—the pressure, perhaps, of some huge body, certainly far more massive than the earth, so far as this evidence goes. Such meteorites would seem to confirm the view already suggested. In the words of Professor Lowell:

> "Here, then, the meteorites tell us of another, an earlier, stage of our solar system's story, one that mounts back to before even the nebula arose to which we owe our birth. For the large body to whose dismemberment the meteorites were due can have been none other than the one whose cataclysmic shattering produced that very nebula which was for us the origin of things. The meteorites, by continuing unchanged, link the present to that far-off past. And they tell us, too, that this body must have been dark. For solid, they inform us, it was, and solidity in a heavenly body means deficiency of light."

Sir Norman Lockyer has maintained for many years that the nebulæ, or at any rate the spiral nebulæ, are composed of meteorites. The most recent study of the nebulæ, by means of the spectroscope, supports this contention. We have already seen that the spectrum of a spiral nebula is not merely the discontinuous spectrum of a gas; and that single fact, long known, is extraordinarily suggestive.

The Growing Evidence that Nebulæ are Composed of a Multitude of Meteorites

More detail, no less significant, has been afforded us in recent years. The spectrum of such a spiral nebula as, we believe, may fairly compare with a stage in the history of the solar nebula is not merely the continuous spectrum of a solid body. On the contrary, it appears to be the spectrum we might expect from an object composed of a multitude of meteorites. The spectrum has a continuous background, such as might be due to glowing but solid and separate meteorites, and it also has bright lines due entirely to glowing gases.

But we have spoken of meteorites as cold and dark, and of those that reach our earth as being broken portions of some dead sun, cold and dark. True, they are warmed and glow externally, when they pass through our atmosphere and are called "shooting-stars," but that is only because of external friction. Inside they are very cold, and answer, as has been said, to the celebrated Chinese dish called "fried ice." The normal temperature of a meteorite, alone in space, is that of space, hundreds of degrees below zero. It scarcely seems evident how a collection of such meteorites could produce a glowing object like the great nebula in Andromeda.

Can it be that These Meteorites are in a State of Incessant Collision?

The key to this apparent contradiction is found if we try to imagine what must be the condition of the meteorites composing a spiral nebula. They are probably moving round their common centre of gravity. Each has its own orbit, and all these orbits must intersect, closely though they agree on the whole. There must thus be incessant collisions; and here is a possibility of brilliance such as we see the spiral nebulæ to display, the brilliance, indeed, whereby we know of their existence at all. If we study the case of meteors in our own solar system we can show that their possible speed of collision might be half a mile a second, or thirty times the speed of an express train.

To quote the words of Professor Lowell, the most recent and authoritative writer on this subject: "As such a train brought up suddenly against a stone wall would certainly elicit sparks, we see that a speed thirty times as great, whose energy is nine hundred times greater, is quite competent to a shock sufficient to make us see stars *en masse.*"

Yet, again, we observe that the spiral nebulæ are brightest towards their centres. This is exactly in agreement with the theory. The collisions of meteorites must constantly tend to make them fall in towards the centre—as the earth would fall to the sun if it were brought up sharp. Thus the nebula would be denser towards its core, with more numerous meteorites travelling at greater speed—just as Mercury travels faster than Neptune. This means that there would be more numerous and more violent collisions towards the centre of the nebula, the superior brightness of which, therefore, supports the theory that meteoritic collisions produce all the light by which we see it.

So far, then, the study of meteorites and of the spiral nebulæ would seem strongly to support the idea of a past meteoritic stage in the history of the solar system, a stage probably coinciding with the first formation of the solar nebula by the collision of two probably, though not necessarily, dark suns.

Observations from Arizona that Seem to Confirm Lockyer's Theory

Recent work done at Flagstaff Observatory, in Arizona, by Professor Lowell and his assistants has introduced us to many new facts regarding the planets, which are in entire accord with the foregoing theory. If the theory be well based, we should expect to find some general contrast between the inner and outer planets of our system. Those which have presumably been formed from the deeper part of the bodies which, as we suppose, were in collision should be denser, and those formed from the outer, which would be the less dense parts of such bodies, should be the lighter. Now, if we take the density of water as unity or one, here are the densities of the principal planets:

Mercury ..	3·5	Jupiter	1·4
Venus	5·1	Saturn	0·7
Earth ..	5·5	Uranus	1·1
Mars	3·7	Neptune.. ..	1·8
Mean ..	4·45	Mean	1·25

The density of the Sun is .. .. 1·41
The density of the Moon is .. .. 3·3

Thus, the average density of the four inner planets, Mars, the earth, Venus, and Mercury, is approximately four times that of the four outer ones, Neptune, Uranus, Saturn, and Jupiter.

This most noteworthy contrast might be explained, perhaps, as regards Jupiter, on the ground of its heat expanding its bulk and making it less dense. But Neptune and Uranus show no signs of being very hot; and, indeed, they are very far from the hot sun. Thus, taking the two groups, we must conclude that the stuff composing the outer planets was originally lighter—which is what we should expect on the collision theory. The material, less dense, on the outsides of colliding bodies would be that which would naturally be flung outermost.

Here the new evidence of the spectroscope is invaluable. Dr. Slipher, at Flagstaff, has produced photographic plates which show the detailed character of the light from the planets further towards the red end of the spectrum than has been possible hitherto. Now it is at the red end of the spectrum that the atmospheres of the planets show their presence and composition best, and hence Dr. Slipher has been able to tell us more, much more, about the atmospheres of the planets than we have ever been able to guess until within the last three years. When the planets are thus made to write their characteristic signatures in colours for our eyes, we find that the character of their atmospheres varies in an orderly way according to their distance from the sun.

Two gases are conspicuous in the envelopes of the outermost planets, and these are the lightest gases known, hydrogen and helium. Especially in the atmosphere of Neptune does free hydrogen exist in large quantities. Careful comparison in the various cases shows that there can only be one explanation for this contrast between the planets. It is not, for instance, that bigger planets can retain gravitational possession of the lighter gases, which fly away from smaller planets. Jupiter is the giant of the planets, but has less of these gases than Saturn, which is smaller. The fact must be that hydrogen, the lightest of all the gases, is most abundant in the atmosphere of Neptune, because the material of this planet is the lightest throughout.

SIR NORMAN LOCKYER IN HIS OBSERVATORY

As Lowell argues, the lighter matter that constitutes both atmosphere and solid substance of the outer planets was lighter because it really belonged to and came from the outer part of the body or bodies involved in the collision whence the solar system came.

"Neptune the outermost, Uranus the next, then Saturn and Jupiter, came in that order from the several successive layers of the pristine body, while the inner planets came from parts of it deeper down. The major planets were of the skin of the dismembered body, we of its lower flesh."

On this quotation only two comments need be made; first, that when Professor Lowell says "in that order," he must mean order in place, not order in time—as the old nebular theory assumed; and second, that he is the nephew of a famous poet, and is not necessarily a worse man of science for frequently clothing his thought in picturesque form.

If we now sum up the evidence, remembering what kind of spectrum a spiral

nebula yields, and what kind of evidence there is that meteorites compose such a nebula; and that their clashing may cause it to glow, we may agree with Lowell when he says:

"Thus do the stones that fall from the sky inform us of two historic events in our solar system's career. They tell us first and directly of a nebula made up of them, out of which the several planets were by agglomeration formed, and of which material they (the meteorites) are the last ungathered remains. And then they speak to us more remotely, but with no less certainty, of a time antedating the nebula itself, a time when the nebula's constituents still lay enfolded in the womb of a former sun."

So much, in outline, for a theory of the evolution of the solar system which is certainly not the nebular theory of Laplace, yet which has a definite affinity to that theory, at least in the later form, including a spiral stage, which recent astronomers have given it. The reader must not expect sharply outlined and contrasted theories. To do so would be to misunderstand the quality and complexity of the evidence. But he will see that the theory of a primarily gaseous nebula is capable of change until we have instead a theory which so largely depends upon meteorites—ignored in the older theories—that we may call it a meteoritic theory of the origin of the solar system.

The "onlie begetter" of this theory is undoubtedly Sir Norman Lockyer, but the outline which we have just given represents a novel form of that theory which differs from his in many particulars, and which no one, least of all its author, can regard as final. Meanwhile it is impossible, before we go on to some new considerations, to refrain from quoting and acclaiming the amazing prevision of the poet Tennyson, writing long before this view, that planets, and the glow of suns, are made by the collisions of meteorites; for in his poem, "God and the Universe," he thus addresses the heavens: "Your boundless nights, Rush of Suns, and roll of systems, and your fiery clash of meteorites."

Let us now try to get a new view of the solar system as a whole, carefully noting those general facts which guide us in understanding its history. It is not enough to have enumerated its parts; we must see their relation. We observe, first, the remarkable flatness of the system. The planets and their satellites, taken as a whole, travel substantially in one plane. The minor planets, though they depart somewhat from this flatness, as if something had happened to push them out of their natural level, yet are not far removed from the same level as the other bodies.

If, further, we are taking a "bird's-eye view" of the solar system, we shall realise for the first time that the sharp distinctions which we were bound to make, in a previous chapter, are not so sharp as the names which indicate them. The case is parallel to that of species of living things upon the earth. We distinguish such species, but on a closer and wider survey we find that they merge into one another, and the "idea of a species" is only an arbitrary one, for our convenience. Really, we now

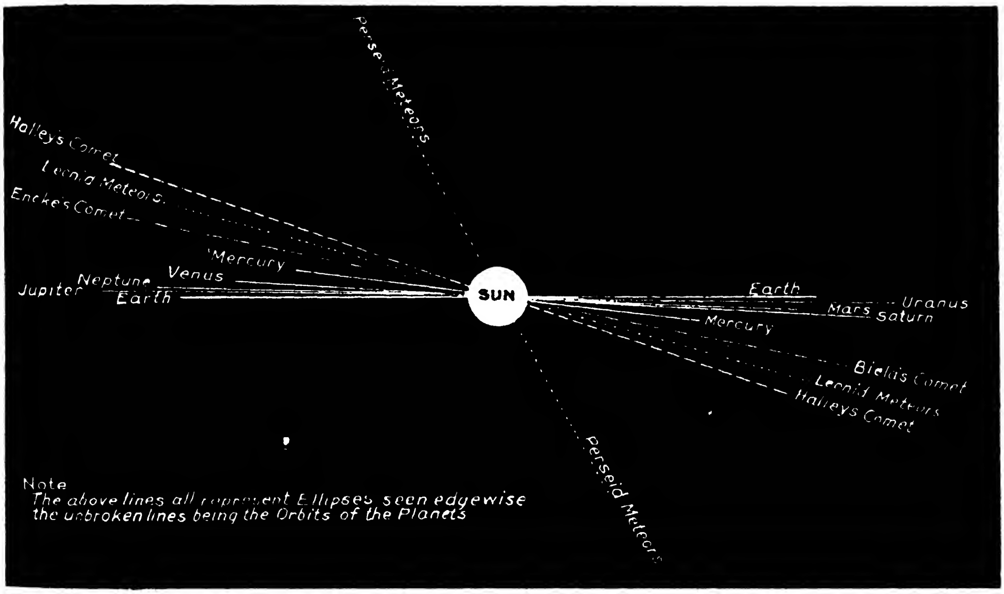
A CRATER IN ARIZONA BELIEVED TO HAVE BEEN FORMED BY THE FALL OF A HUGE METEORITE

This crater, which is some three-quarters of a mile in diameter and 500 feet in depth, exists in a region where there is no sign of volcanic action, but, on the contrary, the earth's crust consists of undisturbed sedimentary rocks. The sandstone and limestone that form the strata give evidence of having undergone tremendous crushing and heat, and meteoric material has been found in the crater. All these facts point to the conclusion that an enormous meteorite fell on to the earth at this spot.

see, all species are connected, and are of common origin.

Just so is it to-day when we make a survey, both closer and wider, of the solar system. In all particulars we find that its different "species," planets, moons, meteorites, and so on, merge into one another. There are many minor planets which are far smaller than many, or any, of the moons of the major planets; and the smallest of the major planets are little larger than the largest of the moons. There is a veritable gradation in size from the sun and Jupiter down to little meteorites which flash for a moment when they strike our atmosphere, "and leave not a wrack behind." The same gradation is true in astronomer what the similar facts of living things mean to the biologist: "It is as fundamental to planets as to plants. For it shows that the whole solar system is evolutionarily one."

The planets are far too interesting and important, and recent work has taught us far too much that is novel about them, for us to deal with them individually at this stage. But we must learn the general, comparative facts of them if the true history of the solar system is ever to be revealed. We must thus observe the very important fact that, on the whole, those members of the solar system which are smallest are also those which travel in orbits furthest removed from a circle, and are,



PICTURE DIAGRAM SHOWING HOW SLIGHTLY THE ORBITS OF THE PLANETS VARY FROM THE SAME PLANE AS COMPARED WITH THE ORBITS OF THE COMETS AND METEOR STREAMS

other respects. The orbit of every member of the sun's family must be an ellipse. Kepler made that declaration, we remember; and the law of gravitation requires it to be so, alike of the planets Kepler knew and of any planets which have yet to be discovered. But ellipses may vary from being all but circles to being all but infinitely longer in one axis than in the other. The members of the solar system display all manner of such variations; and they do the same with their variations from the precise flatness towards which the system as a whole so closely approximates.

This continuity of type, this absence of absolute specific distinction between the members of the solar system, means to the again, those whose very eccentric orbits least conform to the flatness of the plane in which the solar system as a whole is disposed.

These are facts which, like all facts everywhere, must have a meaning, and that meaning will probably help us in our historical study. Already we can surmise that very light bodies, like comets and meteorites, might be the survivors of those that were thrown widest and furthest when the solar system was conceived in the initial collision. Such a view would agree with what we have already learnt regarding the composition of the planets and their atmospheres.

Next let us take a comparative view of another fact of the planets and their satellites. Nothing impressed Laplace more

than the fact that the planets he knew all revolved round the sun in the same direction and in the same plane. The chances against such an agreement are millions to one, unless it be due to some common cause. This agreement is also quite compatible with that collision version of the meteoritic theory which we have already outlined; just as it was in agreement with the gaseous theory of Laplace. But Laplace knew nothing of Neptune. This planet revolves round the sun, but it was found out afterwards that its rotation on its axis, together with that of Uranus, offered an apparent discrepancy.

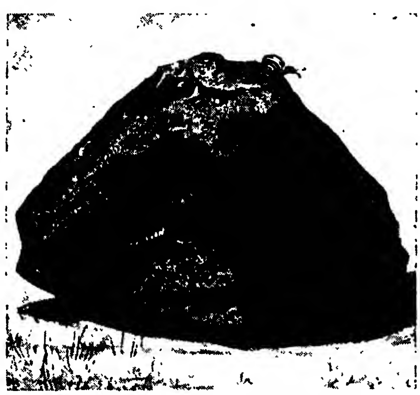
Saturn is somewhat more tilted in his orbit than Jupiter, but Uranus carries this tilt so far that it spins at a right angle to the spin of the inner planets, and at a right angle to its path round the sun, so that it may be described as "wallowing rather than spinning in its orbit." But Neptune carries this a stage further, and actually spins in the opposite direction to its path in its orbit—the opposite direction to the typical spin of the earth or Jupiter, or even Saturn.

But though these new facts seem to agree very little with the uniformity of motions in the solar system, and though no one could explain the reversed rotation of Neptune by the study of that planet alone, if we take the general and comparative view of the planets which is our duty here, we see a new order, in place of the old order which the newly discovered planets appear to have broken down.

It is that if one traces the axes of the major planets, from Neptune successively inwards till we reach the sun, we find that those axes are steadily being "righted," so to say, so that Neptune really spins contrary-wise, because Neptune is upside down, and the successive planets are gradually righted, until we reach Mercury, the innermost, which appears to stand absolutely upright in its orbit, and spin so. Thus a new systematic order is discovered, in place of the simple order which was all that Laplace knew; and from this new order we shall yet be able to infer a more detailed and accurate statement of the origin of the planets.

Somewhat similar, and certainly no less remarkable, is our new knowledge regarding the satellites or moons of the planets. It naturally impressed Laplace that the moons he knew all revolve round their primaries in the same direction as the revolution of these primaries round the sun. The facts known to him remain and bear the general interpretation which he put upon them. We have discovered since Laplace's time no less than thirteen moons or satellites. These include the ninth, Phœbe, and outermost, satellite of Saturn, and an eighth, and outermost, satellite of Jupiter, whose motion is "retrograde," contrary to that of the other satellites and of the planets themselves.

Nevertheless, law is in evidence here also, and we shall learn more from these very exceptions, as they appear to be. The mathematicians are finding a key to them; and meanwhile we observe that the rule which Laplace perceived applies to all eleven of the other satellites discovered since his day. Such a proportion, if we survey the entire series of moons, could not be due to chance, and the two which display so unusual a motion will doubtless turn out to be the exceptions that prove the rules.



A HUGE VISITOR FROM THE SKIES

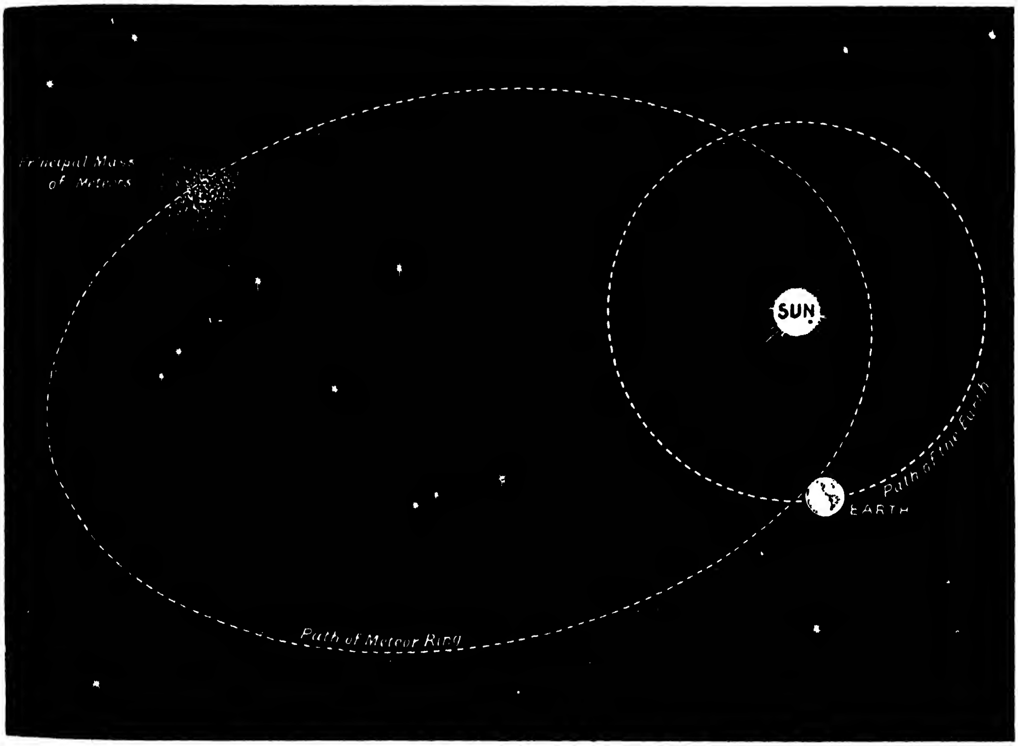
This large piece of meteoric matter, known as the "Caille Aerolite," fell on the Alps. It weighs 1400 pounds, and is now in a Paris museum.

Just so have we found exceptions to the very important generalisation that the moons always move in or near to the plane passing through the equator of their primary—that they circle round its waist, in popular language. We find, however, that the newly discovered moons travel in orbits more and more tilted, as compared with the orbits of the nearer moons and the equator of the planet they belong to. This, too, must mean something; and Professor Lowell may justly recall the fact that each of the five moons discovered in the solar system since he pointed out this rule has confirmed it.

It is evident, as he suggests, that we already know enough of the history of the solar system to be able to make prophecies about it that come true. Yet again we are to observe that, the further the satellites are from their primaries, the more eccentric are their orbits; and lastly, that the satellites which we can observe closely enough lead some astronomers to believe that they always turn the same side to their primary just as our own moon does to us

Such are some of the general facts which the most recent study of the solar system affords us; and we shall see how they contribute, positively and negatively, towards our agreement upon a theory of the origin of our system—a problem so magnificent and tremendous that no efforts and no time are too much to devote to its solution.

We already see that the fire-mist theory of Laplace could not square with the new facts about our system. We learn, also, that the rings of Saturn, later to be studied in detail, do not at all prove, as Laplace thought, the possibility of forming planets out of rings of matter cast off by a whirling nebula.



A DIAGRAM SHOWING THE PATH OF A STREAM OF METEORS, AND HOW THE EARTH IN ITS ORBIT CUTS THROUGH THE METEORS IN THEIR MORE ELLIPTICAL ORBIT

On the contrary, it is more likely that the rings of Saturn are made of meteorites, or bodies of that order, and that they really illustrate the breaking up into meteorites of a formerly continuous body of matter, under the influence of a violent strain.

The argument at this point becomes very complicated, and we must largely trust to the mathematicians where we cannot here follow them. The law of the conservation of the moment of momentum remains. We have already seen its possible bearing on the history of our system. The quantity of motion in the solar system must remain unchanged, but the changes in the balance of the system are unending. If we apply this law, yet again, to the solar system as we have just surveyed it, we find that it explains some of the facts of that survey. Thus it follows from the law regarding moment of momentum that any changes occurring in the solar system will constantly tend towards making bodies move in paths more and more nearly circular, and in paths more and more upon the same plane. This is exactly the same application of the principle as we saw when we applied it to the case of a chaotic nebula, becoming spiral and flat, and to the constant approximation of all the various planes in such a nebula to the principal plane.

It can be proved mathematically that the effect of collisions between particles, and their subsequent fusion—Tennyson's "fiery clash of meteorites"—must always be towards increasing circularity, and increasing flatness of all the orbits involved, if the principle is to be maintained that the quantity of motion in the system must remain constant. Now we understand, for instance, the fact already noted, that it is the small bodies in the solar system whose paths are least circular and least conform

to the flatness of the system as a whole. If these bodies had suffered more collisions, and grown larger, their orbits would be more circular, and more in the plane of the rest.

And here we may add a further argument to the theory as stated by Professor Lowell in 1909. When meteorites fall to the earth in consequence of its attraction, a process which is constantly occurring day and night, what is happening but just this coalescence of small bodies to form larger ones? The formation of a body, earth *plus* a meteorite, is just exactly the process which has made the solar system, according to this modern version of the meteoritic theory.

Countless meteorites are thus being constantly added to the substance of the earth. And now we see that in these cases, so near to us in time and place, the argument holds. For meteors move in eccentric, highly elliptical orbits, and orbits which are inclined at marked angles to the general plane of the solar system. But every meteorite that falls to and becomes part of and one with the earth further pursues a course which is much more nearly circular and much nearer the plane of the solar system as a whole; so that, though the motion of the individual meteor is much changed and apparently lost, the quantity of motion in the solar system as a whole is maintained according to the law.

How Tidal Action Operating through Long Periods Affects Planetary Motions

Similar arguments, though mathematically more complicated, may be inferred from the action of tides. The planets are not perfectly rigid bodies, and each is subjected to tidal deformation by the others, as the satellites are also. This applies equally to solids and liquids and gases.

Now, there is good reason to suppose that tidal action, at work throughout the whole solar system, is constantly tending to reduce it all to the ideal state, so to say, in which it is perfectly flat, and all its parts revolve round the sun in orbits as nearly circular as possible. The retrograde rotations of Neptune and Uranus, the furthest planets, and the retrograde revolutions of the outermost satellites of Saturn and Jupiter, illustrate the state of things which tidal action has already modified elsewhere, and which was originally general throughout the solar system. When any body is rotating contrary-wise to the rest of the system, tidal action, as can be shown, would first turn its axis over, and this would continue until at length the body would be rotating in the same direction as its revolution round the sun. This effect would necessarily be much greater upon bodies near the sun and satellites near their primaries. Thus the exceptions we have discovered since the time of Laplace are simply the last members of the solar system to conform to the forces which control them all.

Lastly, let us ask whether the known temperature of the planets, or, at least, of our own planet, can be accounted for on the theory of formation by "fiery clash of meteorites." So far as can be judged, it seems certain that the clash of bodies enough to form the earth would easily account for the heat which the earth contains. The deeper layers of Jupiter and Saturn seem to be glowing still, and their store of heat could be amply accounted for on this theory of their formation. The heat thus acquired is a planet's invaluable capital.

Though New Heat is Being Formed in the Planets, the Net Balance Favours Cooling

We cannot call it irreplaceable capital, for we must remember the possibility of the evolution of heat by radio-activity. But though the new discoveries regarding radium must enormously extend our estimates of the time involved in the cooling of a planet, yet ultimately it must cool; and we have only to compare the rate of cooling of large and small planets and satellites to see that the essential source of a planet's heat must be that obtained by the concourse of the meteorites which have produced it.

The further stages in the history of such a body thus formed are, in a sense, downwards instead of upwards. Hitherto the planet has been accumulating heat. Now it slowly begins to cool, and, as it cools, what we can scarcely help calling the life of the planet is manifested. At least, this is the period during which our own earth is displaying what we call life.

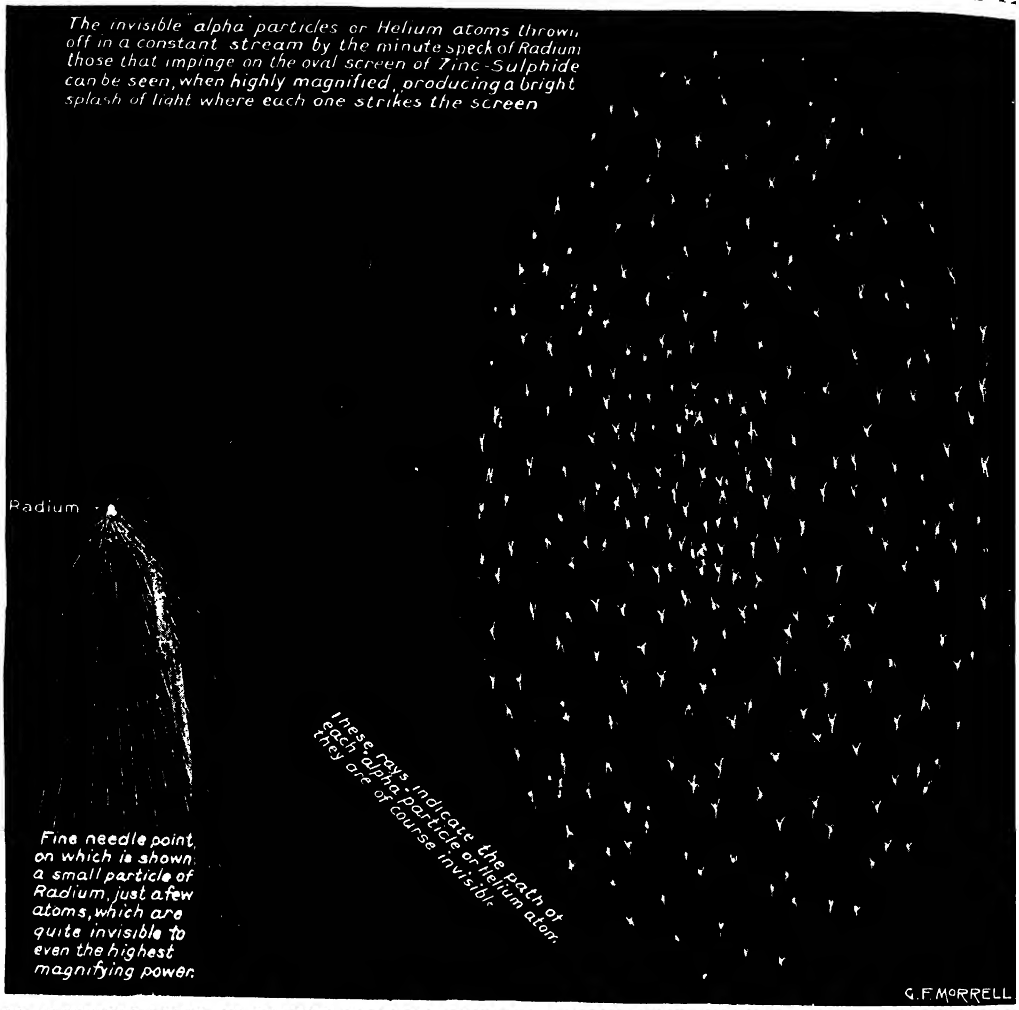
The Explanations of the Forming of Worlds are Theories, not Scientific Conclusions

Such, in brief, is the most recent statement of the making of such worlds as the planets of the solar system, and of the making of such a system as a whole. The reader is not to accept this as scientific conclusion or demonstration. None of those who believe in it most would take it for more than probable speculation, based, at any rate, on the most recent and exact *data* available. But here is, at least, the best representation the human mind has yet been able to make of the manner in which the solar system and its planets have been formed.

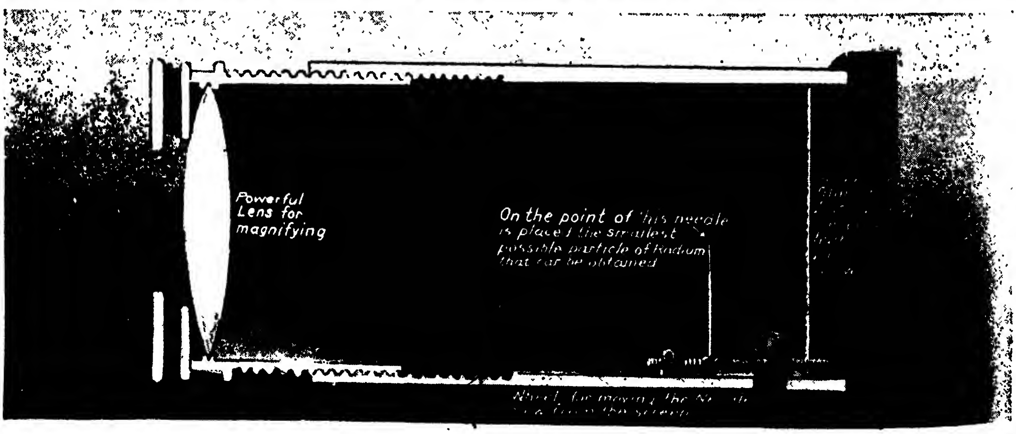
THE STRUCTURE OF A METEORITE

A THIN SLICING FROM A METEORITE, MAGNIFIED TO SHOW THE CRYSTALLINE FORMATION

A VISION OF THE INVISIBLE



AN INVISIBLE SPECK OF RADIUM FLINGING INVISIBLE ATOMS THAT SPARKLE INTO SIGHT ON A FILM



THE SPINTHARISCOPE, WHICH ENABLES RADIUM PARTICLES TO BE SEEN SHIMMERING CLEARLY

These pictures show the means by which the marvellous energy stored up in radium may be observed. From a speck of radium too small to be seen a stream of helium atoms pours forth, and will do so for 2500 years before the radium ceases to exist. The flying particles fall on a zinc sulphide screen or film like hailstones splashing on the surface of water, and the splash is visible, while the radium itself and flying atoms are not. This is the nearest men have yet come to seeing an actual atom.

THE MYSTERY OF MATTER

The Inconceivable Power in Radio-Active Atoms as they Break Up, and its Possible Use by Man

THE MASTER-ENERGY OF THE UNIVERSE

In the last chapter we dealt with the alchemy of the atom, and showed how the dream of the alchemists, the transmutation of elements, is actually realised in the changes undergone by the radio-active substances. We explained how the change is usually something like a disruptive explosion, wherein certain constituent parts of the atom fly off, reducing its weight and altering its characters. We discussed the character of the radiating particles, and found that certain of the larger fragments were helium atoms. There still remains to be considered the *cause* of the explosion. *Why* do constituents of the atoms fly off, and fly off at such a tremendous pace? What is the cause of the instability of the radio-active atom?

This is a question still only half answered, and it probably must remain half answered till we know more about the structure and dynamics of atoms in general; but one thing seems certain, and that is that the cause is intrinsic, and not extrinsic. As we have mentioned before, there is nothing we can do that in any way either retards or accelerates the dissolution of the atom, and the mathematical manner in which the atoms disintegrate cannot be ascribed to any known force. An atom of uranium lives, on the average, for 7,500,000,000 years; an atom of radium A lives, on the average, for 4·3 minutes, and these great differences in length of life indicate that a constitutional cause must play far the greatest part, if not the sole part, in the process of disintegration.

And consider further the energy of the breaking-up atoms. What force do we know that could tear alpha particles out of atoms and send them flying at the rate of five, or ten, or twenty thousand miles a second? The energy that flings the alpha particles out of the atom must have been in the atom in some form or other prior to the expulsion of the particle; and it is probable that radio-active energy that flings forth the particle has been previously employed in whirling it round in an orbit. For thousands of millions of years, perhaps, the alpha and beta corpuscles have been whirling round; and then suddenly one morning they fly off at a tangent, and suggest that the foundation stones of the universe are bombs rather than bricks.

But why, after flying in regular orbits for perhaps thousands of millions of years, should certain corpuscles suddenly break away from the atom? We really do not exactly know, but many interesting and illuminating comparisons and suggestions have been made.

Professor A. M. Mayer, for instance, thrust a number of magnetised needles through corks, and floated the corks in water in such a way that the needles assumed a vertical position with negative poles above the water. Over the needles he suspended a powerful magnet, with its positive pole directed towards the needles. The needles thus tended to repel each other, and yet were drawn together by the attraction of the magnet, and their final position would be the resultant of both forces. Such a scheme represented the dynamical equilibrium in an atom where the negative corpuscles are supposed to repel each other and yet to be held together by the positive electricity of the atom.

Experimenting with systems of this sort, Mayer found that three needles formed an equilateral triangle, four a square, five a pentagon, six a pentagon with a needle in its centre. When he took ten needles, he found that seven of them formed a circle round three arranged as a triangle. When he took fifteen, he found that one needle took up a central position, and was surrounded by a pentagon, which was again surrounded

by a ring of nine. When he took twenty-seven, he found that one central needle was surrounded by concentric groups of five, nine, and twelve.

Professor J. J. Thomson has shown mathematically that similar arrangements and rearrangements must take place in the atom (conceived as a sphere of positive electrification and of a number of negatively charged corpuscles revolving in orbits within that sphere under the influence of the attraction of the positive electricity and of their own mutual repulsions), and that even as pentagons and triangles appear and reappear in the architectural disposition of the needles, so must likenesses in structure crop up in atoms composed of different numbers of revolving corpuscles. He has shown, also, that the periodic instability and alteration by *saltation*, so to speak, of the needles must have their counterpart in an atom of this kind.

On this conception of the atom as groups of corpuscles revolving in concentric rings or spheres, and arranging themselves in such rings according to their number and speed, we can explain many or most of the phenomena of atoms. The triads of Dobereiner, the periodicity with which characters recur in elements with progressive increase and decrease of atomic weight, the grouping of elements in the atomic weight table, their valency, their chemical affinity, can all be explained.

The Marvellous Kaleidoscopic Rearrangement of Electrons that Goes on Inside an Atom

On this conception, too, light can be explained as electro-magnetic radiation caused by the accelerations of the corpuscles as they revolve in their orbits.

Finally, to come to the point from which we started, radio-activity and transmutation can also be explained to some extent on this basis, as changes in the configuration of revolving corpuscles owing to diminution of the energy impelling them in their orbits. Professor J. J. Thomson has shown mathematically that a group of four corpuscles will arrange themselves at the corners of a square if rotating at a certain rate, but that when the velocity falls below a certain critical value they will suddenly arrange themselves at the corners of a tetrahedron. And it is easy, therefore, to understand that in atoms composed of a system of revolving corpuscles an apparently stable configuration may suddenly change when the velocity falls below a certain point. Professor Duncan likens the case to the case of a spinning top. The top spins steadily so long as it spins at a certain rate, but when its velocity of rotation falls below a certain critical value "the crash comes, and away goes the top helter-skelter."

To sum up, then, an atom may be considered as a system of revolving corpuscles whose configuration depends upon the maintenance of a certain velocity of rotation, while radio-activity is due to a rearrangement of corpuscles necessitated by radiation away of energy and consequent diminution of rate of rotation. The rearrangement of the corpuscles further results in a kind of explosion in which certain corpuscles are ejected with terrific force.

An Atom which we Cannot See More Elaborately Organised and Tuned than a Piano

Whether this theory of corpuscular rotation and explosive rearrangement be true or not, its concordance with facts, "almost Satanic in its exactness and verisimilitude, forces us irresistibly to believe that in these hypothetical systems of revolving corpuscles we have models which reflect in some really intimate way the structure of the mysterious originals."

Considering the dynamical and structural complexity of atoms, it is surely marvellous that each is ordinarily so true to type. The late Professor Rowland, of Baltimore, pointed out that atoms are more delicate and complex mechanisms even than grand pianos. Yet atoms are much more accurately attuned in unison than grand pianos can possibly be. "Two pianos," writes F. Soddy, "would be regarded as in perfect tune together when there was a comparatively rough approximation of period between the various notes. Whereas by the spectroscope a difference in 'tune' or period in the vibrations emitted by different atoms of only one part in many millions would be easily detectable, and no such variation exists."

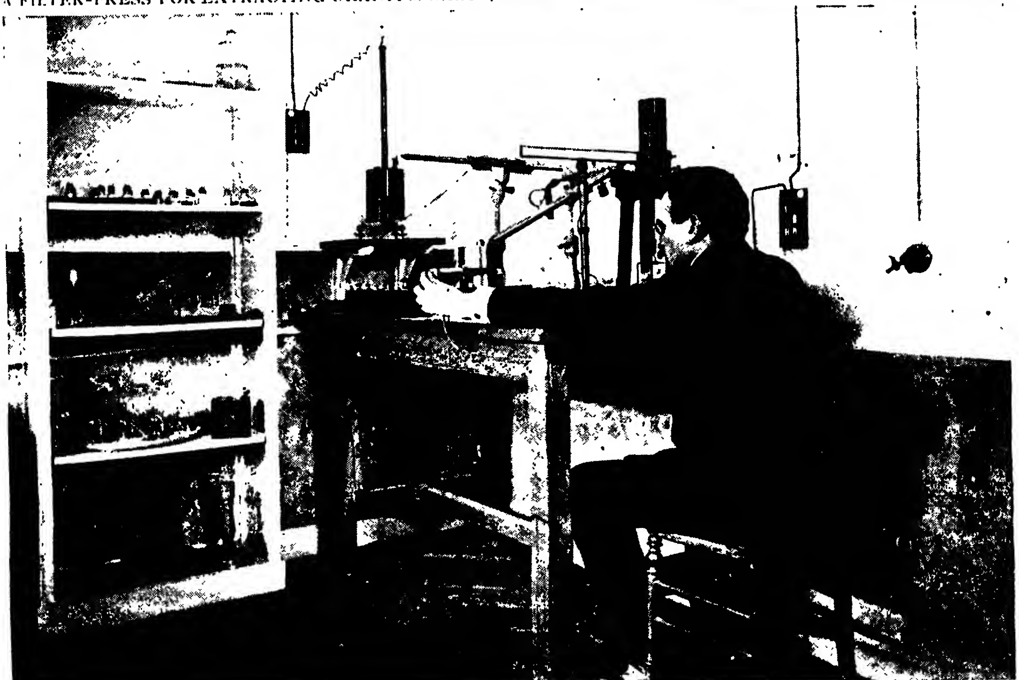
The Explosions in an Atom of Radium that go on Giving Heat for Thousands of Years

Even in death the atoms are not divided; they break up with the same precision and unanimity. All the alpha particles of any radio-active element are expelled at the same velocity. The alpha particles of uranium fly at 9600 miles per second; the alpha particles of radium A at 11,000 miles per second; the alpha particles of radium C at 12,800 miles per second, and each explosive atom expels its fragments at a definite and fixed velocity.

Let us now consider more in detail the amount of energy set free in the explosion of a radio-active substance.

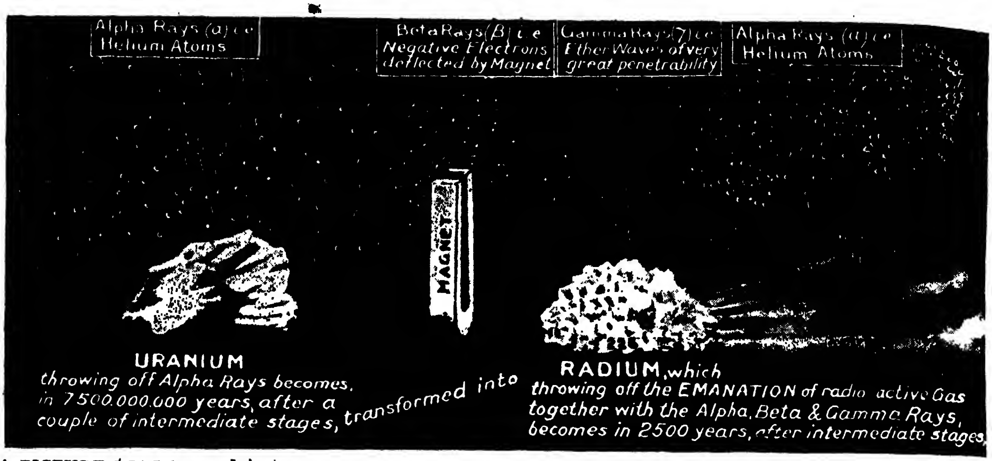
MAKING THE DEAREST THING ON EARTH

A FILTER-PRESS FOR EXTRACTING URANIUM SALTS, THE MOST IMPORTANT RADIUM-HOLDING MATERIALS



MEASURING THE RADIO-ACTIVITY OF SALTS CONTAINING RADIUM, AS THEY ARE MORE AND MORE PURIFIED

Radium, which has not yet been separated pure, but in its most potent form as a chemical compound is worth more than £400,000
an ounce, is found in infinitesimal quantities in combination with other substances. Thus a ton of pitchblende residues, when treated
for 2½ months with five tons of chemicals, and washed with fifty tons of rinsing water, will produce from two to four pounds of radium
bromide of low radio-activity. This salt, under successive purifications and crystallisations, leaves smaller amounts of radium with
a higher radio-activity, until only one-thirtieth to one-sixtieth part of a grain of radium remains from a ton of residue; but its radio-
activity will be forty thousand times greater than that of the larger mass of radium bromide first obtained. Photographs by Dr. Gradenwitz



A PICTURE-DIAGRAM SHOWING THE DISINTEGRATION OF THE CHIEF RADIO-ACTIVE SUBSTANCES

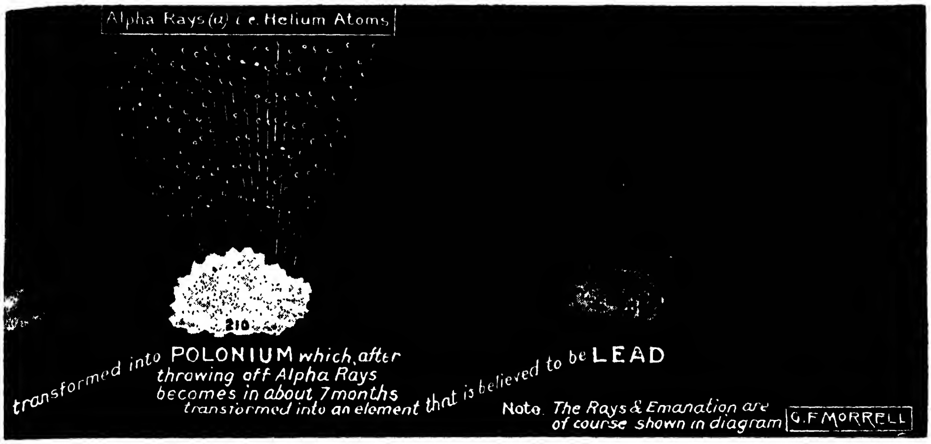
A mere change of one element into another—a change of uranium into radium, of radium into polonium, of polonium into lead—is certainly a wonderful thing, and it would be more wonderful still if we found lead change into gold, but the wonder of the transmutation cannot compare with the wonder of the force exhibited in the process.

A volley of alpha particles on a screen coated with zinc sulphide may not seem such a terrific thing as the explosion of a ton of dynamite or even of a pint of petrol, but it is nevertheless the manifestation of a prodigious energy far surpassing the wildest dreams of man. All forms of energy, heat, electricity, motion, are interchangeable; and, as might have been expected, it was soon discovered that radium gives off heat, due to the bombardment of its own substance by its alpha particles; and this heat in itself is sufficient to show the prodigious energy of the particles.

The heat produced in this way is sufficient to keep radium about 2·7 deg. Fahrenheit hotter than the surrounding air, sufficient to raise a quantity of water of the same weight from freezing point to boiling point in one hour. And heat continues to be produced at this rate not for one hour, not for one day, not for one year, but for thousands of years. The greater part of the heat is produced by the energy of the alpha particles of the radium emanation. A thimbleful of this emanation would contain about seven million calories of heat, or heat sufficient to raise 15,000 pounds of water one degree. Weight for weight, the heat evolved by the radium emanation is nearly a million times greater than that let loose by any known chemical reaction. No vessel known would hold a pint of radium emanation, for the heat generated by a pint of the emanation would instantly melt and volatilise any material known—even platinum would melt like butter.

A pound of the emanation would give off energy at a rate corresponding to 10,000 horse-power. But radium itself gives forth in a few years many hundred times as much energy in the form of heat as can be obtained from an equal weight of any other substance in any way whatsoever, and from first to last can produce about 250,000 times as much energy as is produced by the combustion of an equal weight of coal; while uranium, though its evolution of energy is much slower, has 14 per cent. more energy than radium. The energy is there in the uranium, but only one-seven-thousand-five-hundred millionth of it becomes active yearly, so that it is difficult to realise its enormous total potency.

In the case of the emanation and of the radio-active deposit of radium, almost the whole energy comes into action within a few minutes or hours, and, accordingly, most minute quantities make their energy manifest. In the construction of the instrument devised and called by Sir William Crookes the spinthariscope, for instance, the amount of radium, and accordingly of radio-active deposit, used is infinitesimal, so infinitesimal as to be invisible to the microscope and quite unweighable by the finest balance. This instrument contains a needle which is made to touch a tiny phial that once contained radium—that is all—and yet this invisibly small quantity of radio-active material will batter away at the zinc sulphide for hundreds, perhaps thousands, of years. If we take a minute bubble of radium emanation of the volume of the thirtieth of a pin's head and put it into a globe dusted with sulphide of zinc the



THE TRANSMUTATION FROM URANIUM TO RADIUM, FROM RADIUM TO POLONIUM, AND FINALLY TO LEAD

globe will shine thenceforth "with a soft white light like some fairy lantern."

There is no denying the energy of substances which can produce these effects even in such infinitesimal quantities. We might not believe our eyes if we were to see an imponderable ghost, but an infinitesimal quantity of radio-active matter which is both invisible and imponderable writes its signature in light, and brands its name in heat and electrical energy so that we *must* believe in it. Soddy was able to detect helium formed from uranium and thorium though in quantity only one-five-hundred millionth of the mass of the uranium or thorium *per annum.*

An observer can actually sit down in front of a vessel, and, with the aid of a watch, count the number of alpha particles entering it every minute from a quantity of radium outside, so that we know by actual counting and calculation that a grain of radium shoots forth about ten thousand million alpha particles per second. When we remember that a portion of matter consisting of a billion alpha particles would be only barely visible by the microscope, and that it would require more than a trillion of them to affect a delicate balance, we can understand how enormous must be the energy of these tiny particles before they can give evidence of their individual existence.

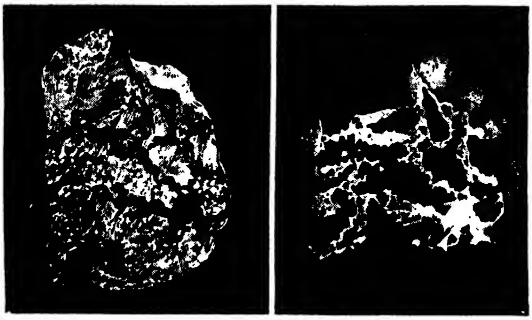
The bolometer will register the heat of a candle a mile and a half distant; the spectroscope will detect one one-hundred-and-eighty millionth of a grain of sodium; yet these instruments are not so wonderful as the smear of zinc sulphide that scintillates under the impact of a single atom. A single helium atom can *never* by a microscope be seen, can never by the most delicate balance be weighed, can never be detected by the most perfect spectroscope or bolometer, yet its energy can be beholden as a flash of light on the zinc sulphide screen. As it darts through the air, too, with a velocity forty thousand times that of the swiftest rifle bullet, it splinters and electrifies about a hundred thousand molecules of air, and by this electrical effect the alpha particles can be readily detected. The path of alpha particles is always strewn with broken and electrified air molecules; and one has but to test the electric conductivity of the air by means of a gold-leaf electroscope to find if alpha particles have passed through it.

Professor Soddy declares that if half a grain of radium bromide were divided equally among all the human beings at present alive in the world he could detect and identify every portion with the greatest ease by means of a gold-leaf electroscope.

By an adaptation of a gold-leaf electroscope Professor R. J. Strutt has made a clever instrument known as the radium clock. A very minute quantity of radium is put into a thin-walled closed glass tube which carries at its lower end two gold leaves. The tube and gold leaves are insulated in a highly exhausted glass vessel. The beta particles—which, it will be remembered, are charged with negative electricity—pass through the glass of the inner tube, and, since they carry away negative electricity, leave the radium positively charged. The positively charged radium, in turn, charges the gold leaves with positive electricity, and they accordingly repel each other and gradually diverge, but when they have diverged a certain distance they touch the sides of the outer vessel, and are discharged, and fall together again. Again they become charged with positive electricity, and diverge, discharge,

and collapse, and this rise and fall goes on as long as the radium is radio-active. The leaves in the clock made by Professor Strutt have been rising and falling once in three minutes for eight years, and there is no reason why they should not go on rising and falling for at least a thousand years.

The energy of the flying particles of radio-active substances depends mainly upon their velocity. Fifteen grains of radio-active matter moving with the speed of light would have energy enough to lift the British Navy to the top of Ben Nevis; and a French scientist declares that an amount of such substances, only equal to the head of a pin spinning fast enough, might have a mechanical power equal to several thousands of locomotives. It is the tremendous speed of the radiated particles that gives them their power. Now, just as much energy as we see manifested in the few exploding atoms must be contained in the intact atoms. The beta particles in the atoms of gold and silver and lead, for instance, must be whirling in their intra-atomic orbits with about as much energy as is displayed by the beta particles that fly off from radio-active bodies. And so we come to the amazing conclusion that the atoms are reservoirs of enormous energy —reservoirs of energy such as the world has never dreamed of.



DARK PITCHBLENDE AND ITS AUTO-PHOTOGRAPH

The left-hand picture shows a piece of polished ore of felspar, quartz, and hornblende, in which lie dark layers of pitchblende. When Sir William Crookes placed this on a sensitised plate in total darkness, the result was the photograph shown on the right, in which the pitchblende appeared light owing to the emanation of radium contained in it.

Mechanical energy directed by mind has been the lever of civilisation and the main-spring of progress, and every discovery of a new source of energy has promoted the welfare of humanity. Take coal, for instance. For thousands of years the energy latent in coal lay idle, unused, and unknown. Then man discovered fire, and, finally, found in fire and steam means to release and utilise the coal's dormant energy. With this energy he made machinery do the work of millions of men. All over the world oxygen is leaping at hot coal; all over the world molecules of water are bombarding ponderous pistons and turning wonderful wheels to abet the ambitions of man. Always on the outlook for more energy, man has also discovered gunpowder and dynamite, and petrol, and has harnessed even the winds and the waves to the chariot of his civilisation. And now he has found this new weighty culminating energy of the whirling particles of the atom; and the only question is how fully he can avail himself of this new prodigious power.

We find the energy most ready to hand in radium and its products, but radium is scarce and dear, and its disintegration is slow, so that at present it cannot be turned to any very useful account; and the most we can hope from it are thousand-year clocks, and perhaps thousand-year phosphorescent lamps. Of uranium, however, there is plenty; and though its disintegration is slower still, and though it takes thousands of millions of years to release its energy, yet it is always possible that some means may be found to accelerate its explosive disintegration and give us a million years' energy in a few moments.

Now that we know that such energy is in the atom we *must* find a means of getting it; it is merely a question of liberation, conversion, and redirection of the energy already in action holding the constituents of the atom together, and impelling them at a terrific speed in infinitesimal orbits. Already we can widen the orbits by means of heat, and thus obtain the energy of a gas, already we can perturb the orbits by means of magnetism; and the day will surely come when we shall be able to turn the whole enormous rotational energy of the corpuscles into useful translational form. Professor Rutherford has even suggested that, with a proper detonator, it might be possible to start an explosive wave of atomic disintegration which would break up the whole world, and leave nothing but a wrack of helium behind, and Soddy imagines that a cataclysm of this kind occurred long ago in the past. "The legend of the Fall of Man," he thinks, "possibly may indeed be the story of such a past calamity."

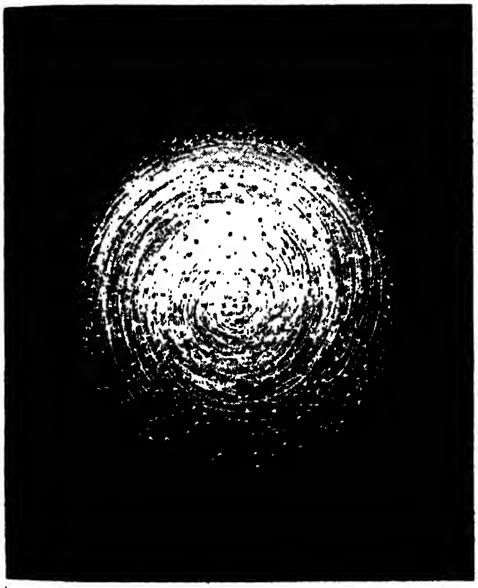
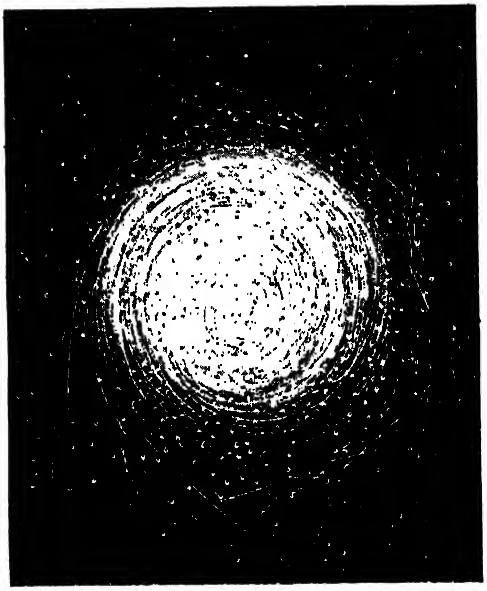
All thinkers are agreed that the discovery of a means to accelerate or initiate the explosion of atoms will be the greatest discovery in the history of the world. "The scholar," says Le Bon, "who discovers

the way to liberate economically the forces which matter contains will almost instantaneously change the face of the world. If an unlimited supply of energy were gratuitously placed at the disposal of man, he would no longer have to procure it at the cost of arduous labour. The poor would then be on a level with the rich, and there would be an end of social questions."

"A race," says Soddy, "which could transmute matter would have little need to earn its bread by the sweat of its brow. If we can judge from what our engineers accomplish with their comparatively restricted supplies of energy, such a race would transform a desert continent, thaw the frozen poles, and make the whole world one smiling Garden of Eden. Possibly they could explore the outer realms of space, emigrating to more favourable worlds, as the superfluous to-day emigrate to more favourable continents."

Again: "It cannot be denied that, so far as the future is concerned, an entirely new prospect has been opened up. By these achievements of experimental science Man's inheritance has increased, his aspirations have been uplifted, and his destiny has been ennobled to an extent beyond our present power to foretell. The real wealth of the world is its energy, and by these discoveries it, for the first time, transpires that the hard struggle for existence on the bare leavings of natural energy in which the race has evolved is no longer the only possible or enduring lot of Man. It is a legitimate aspiration to believe that one day he will attain the power to regulate for his own purposes the primary fountains of energy which Nature now so jealously conserves for the future. The fulfilment of this aspiration is, no doubt, far off, but the possibility alters somewhat the relation of Man to his environment, and adds a dignity of its own to the actualities of existence."

Years ago Berthelot, the great French chemist, made a similar prophecy: "When energy can be cheaply obtained, food can be made from carbon taken from carbonic acid, hydrogen taken from water, and nitrogen taken from air. What work the vegetables have so far done, science will soon be able to do better, and with far greater profusion, and independently, too, of seasons, or evil microbes, or insects. There will be then no passion to own land, beasts will not be bred for slaughter, man will be milder and more moral, and barren regions may become preferable to fertile, as habitable places, because they will not be pestiferous from ages of manuring. The reign of chemistry will beautify the planet. There will be no need under it to disfigure the earth with the geometrical works of the agriculturist, or with the grime of factories and chimneys. It will at last recover naturally its verdure and flora." Such is the radiant prophecy of the

THE THEORETICAL DIFFERENCE BETWEEN AN ATOM OF ORDINARY MATTER AND AN ATOM OF RADIO-ACTIVE MATTER

radio-active elements. And it must be understood that we shall not require radio-active material by the ton or even by the pound. A very few grains of intra-atomic energy will suffice to do great things.

Sir J. J. Thomson has estimated that a few grains' weight of hydrogen has sufficient intra-atomic energy to raise a million tons to a height of more than three hundred feet. Le Bon has calculated that there is enough intra-atomic energy in a copper one-centime piece to impel a goods train along a horizontal line for more than a hundred thousand miles—as much energy, that is to say, as would be produced by about three million kilogrammes of coal, costing about seventy thousand francs. With a tablespoonful of salt we might destroy a city, and we could keep in a flask enough concentrated fuel to take many Mauretanias and Olympics across the Atlantic.

Will the Masters of the Secrets of the Atom Be the Masters of the World?

We simply require to know how to explode the atom to obtain almost inexhaustible energy; and the day will probably come when the burning of wood and coal and oil to obtain energy will be looked upon simply as an example of how not to do it.

The larger atoms with the heavier atomic weights contain the most energy, and they also are the most explosive, as is seen in the case of uranium, thorium, and radium, and probably it is the heavier atoms that will first be compelled to work for man. Most likely, too, the first step will be to hasten the explosive processes already taking place in the known radio-active elements; and it may be a prophetic insight into the future that induces the Austrian Government to prohibit the exportation of radio-active ore; for the country that first conquers the radio-active atom and that possesses radio-active ore will conquer and possess the whole world. Lucky, perhaps, it is for us in this land which lives by force that we also have radio-active ore.

The Power of Gold as a Reservoir of Force and Not for What it Can Buy

Once, however, the radio-active atoms are brought under control there is little reason why the heavier atoms should not be controlled too; and perhaps the day will come when gold, one of the heaviest metals, will be used not as a medium of exchange but as a source of energy. Then, when we want to go from Paris to Pekin, we shall not require to buy a ticket with gold, but will utilise the intra-atomic force of half-a-sovereign to take us there. So all the wealth of Britain will be converted into useful work. Bracelets and rings will be no longer ornamental but useful; and to wear them as ornaments will appear a foolish, barbaric anachronism.

But radium has given the world more than visions of power: it has taught us the mystery of matter, and has shown us the supernatural in the natural. We have mentioned the fact that the smallest particles of matter known, the beta corpuscles or kathode rays, carry charges of negative electricity. But it would seem probable that the beta corpuscles consist of electrical charges, and of nothing but electrical charges; and if this be so, then matter itself, which is built up of such particles, is in its ultimate stage nothing but electricity.

The most distinctive quality of matter is its inertia—that tendency in it to resist movement when it is at rest, and to continue moving when once in motion. We know the strain it is to horses to start a heavy vehicle, and we know likewise that when the vehicle is started it may require a great effort on the part of the horses to pull up quickly. In every instance matter shows this reluctance to start and to stop, and the measure of its reluctance is the measure of its mass.

Are the Electrons that Whirl in an Atom on Their Way to Nothingness?

But it was proved by Sir J. J. Thomson thirty years ago that if a sphere be charged with electricity its inertia is increased. And Sir Oliver Lodge calculated that the inertia of a sphere moving at half the speed of light is increased 12 per cent., at three-quarters the speed of light, 37 per cent., while at speed approaching the rate of light it was increased 400 per cent., and at the speed of light increased to infinity.

Now, in the case of these beta corpuscles, we have little bodies moving with a velocity approaching the velocity of light, and the question is how much of their apparent mass is material and how much electrical. Sir J. J. Thomson considered this question mathematically, and came to the conclusion that the whole inertia of the particles may be accounted for by the inertia of their electrical charges in motion, and that therefore the particles may be considered electrical charges and nothing but electrical charges. Consequently, matter in its last analysis is nothing but electricity. Conceived in this light, the negative corpuscles are usually called electrons, and the theory of the electrical foundations of matter is usually called the electrotonic theory of

matter. By this electrotonic theory, static electricity, current electricity, magnetism, light, radio-activity, and other phenomena may be explained.

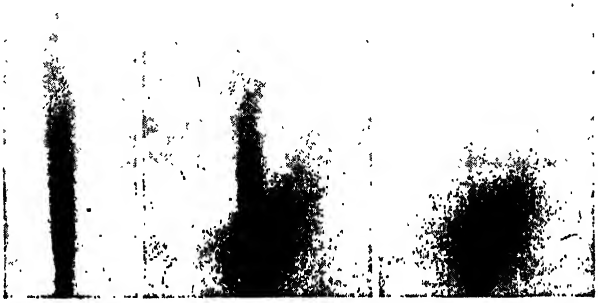
The theory has startling implications, for electricity is nothing but ether waves, and even as waves gradually die away so may the electrons die away into the nothingness of ethereal calm. So on this theory

"The cloud-capped towers, the gorgeous palaces,
The solemn temples, the great globe itself,
And all which it inherit shall dissolve,
And, like this unsubstantial pageant faded,
Leave not a wrack behind."

Le Bon puts the matter very clearly: "These vibrations of the ether, ever the companions of the electric atoms, most likely represent the form under which these vanish by the radiation of all their energy. The electric particle, with an individuality of its own, of a defined and constant magnitude, would thus constitute the last stage but one of the disappearance of matter. The last of all would be represented by the vibrations of the ether, vibrations which possess no more durable individuality than do the waves formed in water when a stone is thrown into it, and which soon disappear." Again: "It is no doubt the same with the vibrations of the ether. They represent the last stage of the dematerialisation of matter, the one preceding its final disappearance. After these ephemeral vibrations, the ether returns to its repose and matter has definitely disappeared. It has returned to the primitive ether from which hundreds and millions of ages and forces unknown to us caused it to emerge, as it emerged in the far-off ages when the first traces of our universe were outlined on chaos."

Considered thus, matter is surely the miracle of miracles, the most mystical of all things mystical, for, after all, the ether is known to us only by a certain periodicity in the forces that play upon our consciousness, and is merely the hypothetical medium of these forces. We are obliged by the constitution of our minds to assume a medium for the propagation of waves, even as we formerly assumed a *substance* in which the properties of matter inhered, but this medium is surely immaterial: we cannot see it, we cannot weigh it. When, therefore, we analyse matter into ether waves we dematerialise it and conceive of it as periodic forces, which, like all forces, are really subjective phenomena.

Matter, then, is nothing but mental effects of a certain kind produced by forces neither visible nor ponderable. All the whirling worlds and whirling atoms are merely our subjective projections of various forms of force impinging upon us. Nor can we empty the idea of force of its psychical significance. The term and the idea are derived from our own conscious action; and the very moment we identify matter with force we identify it with conscious will and conscious being. There is no way out of it. What was formerly called the substance of matter is now known to be force, and the force may well be supposed to be the soul or Will of God.

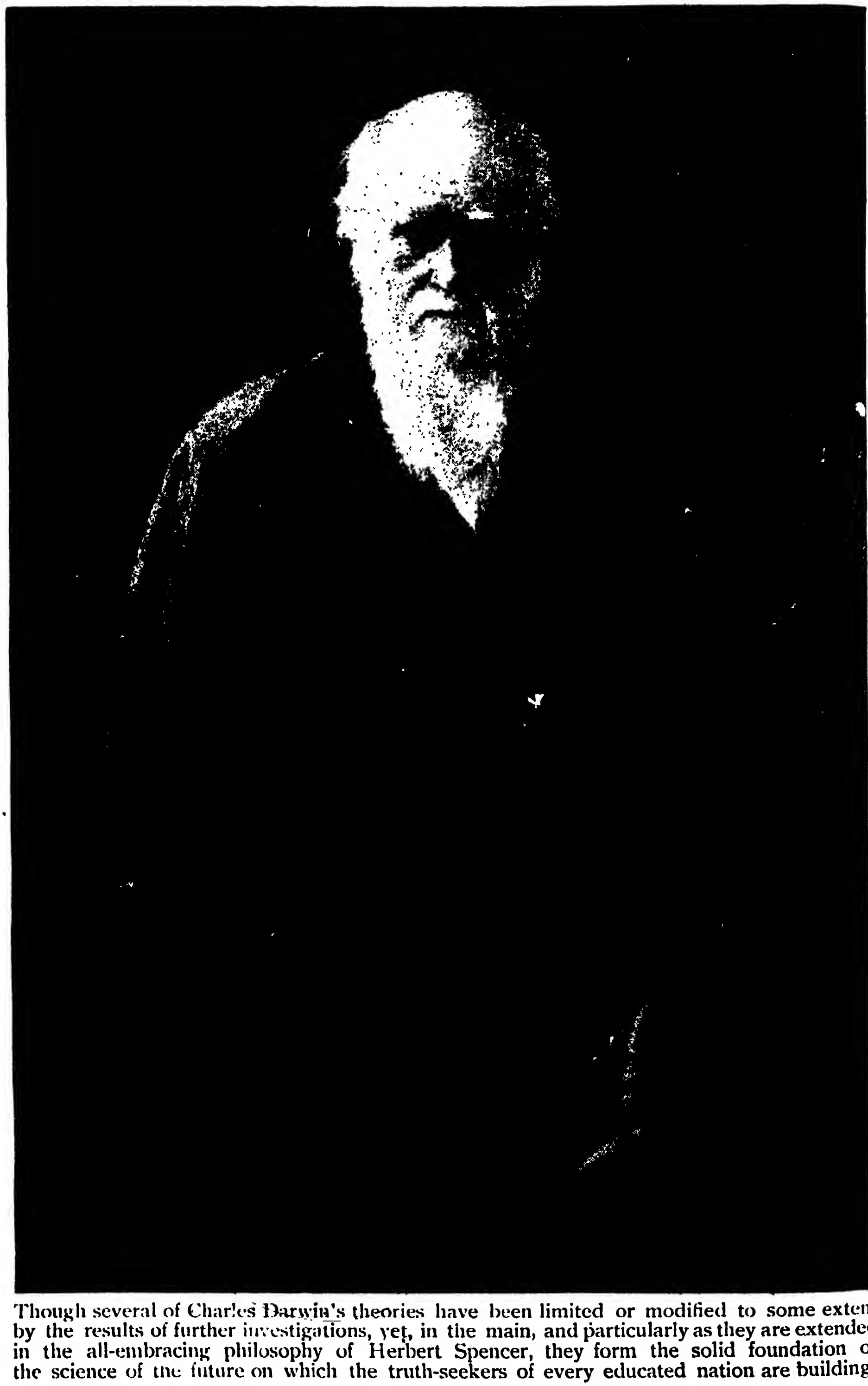


THE RAYS EMANATING FROM RADIUM

These photographs, by Sir William Crookes, show how a magnet can cause deflection of the rays. This is seen in some degree in the middle photograph, but more clearly in the third photograph, where the Alpha rays have been cut off and Beta rays left.

But it may be said the casual force is not eternal. The grip of God relaxes; the atom decays; the force becomes ripples; the ripples die away into motionless ether, which is annihilation. No; complete cessation of force is incredible; it is not abolished, it is merely redistributed; it is "the same yesterday, and to-day, and for ever." In the noble words of Herbert Spencer: "That which persists unchanging in quantity but ever changing in form, under these sensible appearances which the universe presents to us, transcends human conception, is an unknown and unknowable power which we are obliged to recognise as without limit in space and without beginning or end in time."

THE GREAT PIONEER OF EVOLUTION



Though several of Charles Darwin's theories have been limited or modified to some extent by the results of further investigations, yet, in the main, and particularly as they are extended in the all-embracing philosophy of Herbert Spencer, they form the solid foundation of the science of the future on which the truth-seekers of every educated nation are building.

This portrait of Charles Darwin is photographed by Mr. Emery Walker from the picture in the National Portrait Gallery by the Hon. John Collier. The photograph of Dr. Alfred Russel Wallace, on page 1279, is by Mr. A. E. Hoppé; and other photographs that illustrate this article are by Mr. J. J. Ward.

LAWS OF RACIAL CHANGE

Two Great Men's Competitive Discoveries of How the Fittest are Selected to Survive

A SOMETHING MORE THAT DARWIN MISSED

"EVOLUTION was in the air"; no one could doubt that living species were descended from other and simpler forms; but the obstinate *how* remained, and there were no answers which satisfied even those, such as Huxley, who most anxiously desired them. Scarcely anyone noticed Spencer's work, and his arguments, in many a conversation, did not convince Huxley. For lack of some convincing assertion of a *method* of organic evolution, the battle between "creationists" and "evolutionists"—to use terms which are now themselves passing into the past—seemed something like a stale-mate. Into this half-frozen sea of thought Charles Darwin launched, in 1859, the ice-breaker called "The Origin of Species," whose keen prow has never ceased to crash onwards ever since. Our business here and now is to learn what Darwin taught, to weigh its significance for his own time, and, above all, to analyse very carefully, in the light of our knowledge to-day, the exact worth and precise limits of the central doctrine which we associate with his name.

Already in 1839, at the age of thirty, Darwin had abandoned the view that species are immutable, and had opened and filled his first notebook of facts that might explain how they change. For nearly twenty years he worked steadily at the subject, accumulating evidence that more and more clearly pointed to the truth of a theory which early suggested itself to him. Then, in 1858, a young naturalist sent him, from the other side of the world, a brief account of the very same theory, in very similar language, asking his opinion thereon, and his help, if he saw fit, for its publication. Darwin naturally concluded that he must at once publish the paper, and lose the honour of priority to which men of science alone attach any value—though the theory had been framed by himself many years before, and though he was only waiting to add to the immense stores of evidence which he had already gathered.

Illustrious friends were consulted, and the plan was followed, with the consent of both authors, of reading a joint-paper before the Linnæan Society. This was done in 1858. Exactly half a century later, in 1908, that society held a meeting—never to be forgotten by the few fortunate enough to be there—at which Darwin's young comrade of fifty years before was present, and was the first recipient of the Darwin-Wallace medal, struck in honour of the two men whose work, whose dignity, and personal faithfulness and humility are an unique and incomparable page in the history of thought. Dr. Alfred Russel Wallace, the "Nestor of Evolution," is still alive, and in his ninetieth year is now using his unweary pen to advocate the great cause of eugenics, or "Race-Regeneration," which is so largely based upon that doctrine of selection wherewith his name is imperishably associated.

Natural selection was the phrase which Darwin introduced to express the theory in question. It is not a good term, for it is not self-explanatory, and it seems to point to some conscious agency that selects. It has a still more serious defect, which we shall later consider. We may ask how Darwin came to use a term that has such drawbacks. The explanation is that he wished to show the parallel between "natural selection" and artificial selection.

A patient and copious student of animals and plants under domestication, he saw that species of living things are capable of profound modifications, such as the racehorse or the pouter-pigeon or the sweet-pea, by the process of deliberately selecting certain kinds to breed from. But being

not only a great observer but also a thinker, it occurred to him that what conscious agency accomplishes in such cases other agencies may be conceived to accomplish in the case of animals and plants that live in natural conditions; so that, just as the human breeder selects the types he desires and breeds from them, and makes new forms, so Nature, the breeder of all living things, including men, somehow selects certain types and so makes new species. Natural selection is thus an argument by analogy from artificial selection.

The Theory of a Mathematical Philosopher that we are Heading Towards Starvation

But how, we may ask, did this idea occur to Darwin? The answer is of double interest, as a notable illustration of the growth of thought, and as a suggestive contribution to the great controversy which now rages about the effect of a falling birth-rate.

In his famous "Essay on Population," first published in 1798, the Rev. Thomas Malthus had discussed the consequences of the growth of human population faster than the food-supply to sustain it. There could be no more "topical" subject at this hour, considering where the food-supply of our own growing population comes from. Malthus argued that population tends to increase in geometrical progression—like 3, 9, 27, 81, 243—while food-supply can only increase in arithmetical progression—like 3, 6, 9, 12, 15. Plainly someone must starve. From these considerations, which are here neither accepted nor denied, Malthus argued for late marriages, in order that the growth of population might be slower, and that the "struggle for existence," as Dr. Wallace called it many years later, might be less terrible for the poor.

Inferences Drawn Simultaneously by Great Thinkers half the World Apart

Darwin read this essay in the 'forties, and Dr. Wallace read it in the late 'fifties. To each of them the same idea occurred. Their minds were running on the same theme; they had similar facts and observations already digested, and ready to be assimilated and made into vital thought. Dr. Wallace was lying in bed under the sky of the Southern Seas, recovering from a "hot fit" of malaria, when he saw the inference from the theory of Malthus. "Someone must starve," we have said. And who should the someone be? If two men run to one loaf of bread, who will get it? Or if the two fight, who will get it? We see the answer now. A factor of selection has been discovered, which parallels the work of the human breeder. There must be what Spencer called the "survival of the fittest"—which instantly explains the everywhere illustrated fact of fitness or adaptation between an environment and the species that inhabit it.

If food is to be run for, or if one must run in order to avoid being eaten by someone else, then fleetness is fitness; and fleetness survives, together with those kinds of bodies and limbs that make for fleetness. If, on the other hand, to be immobile and pretend to be dead or uneatable is to survive the attentions of the would-be eater, then those creatures who are cleverest at looking like pieces of stick, or dead leaves, or what not, will be the fittest, will survive, and will leave offspring like themselves, among whom the same selection occurs, until we find the staggering adaptations, mimetic resemblances, and so forth, which Dr. Wallace and others have since studied for us.

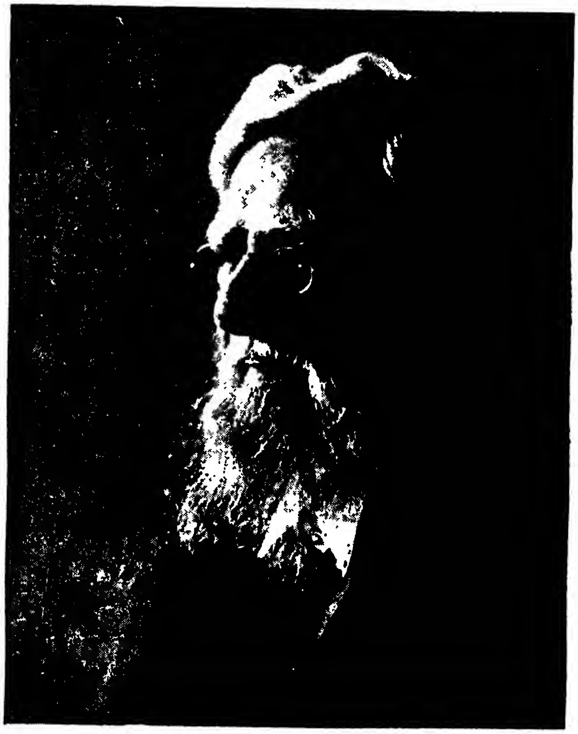
The Mistakes of the Mathematical Philosopher in Framing his Alarmist Theory

Clearly, then, natural selection is not an inevitable and constant factor in the course of animal and vegetable life; nor is it purposeful, deliberate, intentional, with an ideal to aim at, like the artificial selection by the human breeder, to which Darwin likened it. Yet it acts as if it had an ideal; and that ideal is adaptation. Just so does a sieve act, quite mechanically, as if it had an ideal, provided that the necessary conditions for its working are present. It is now our business to note, very carefully, the three cardinal and indispensable conditions which natural selection requires for its action.

Malthus had seen the first, and suggested it to Darwin and to Dr. Wallace, when they read his essay. It is over-production of new lives, so that not all can survive. The essential meaning of "over," in this definition, is in relation to available food. Natural selection has various forms, but the typical and general form, far more important than all the others put together, is that of a competitive struggle for an inadequate food supply. When we say *over*-production, we mean that the food-supply is inadequate. In this principal form of natural selection—not in the popular misinterpretations of the term, but in the strict scientific sense—the process ceases directly the production of new life falls to the level of the available food, or directly the food-supply is increased so as to be adequate for all comers. The great, representative instance of natural

selection, as understood by Darwin and Dr. Wallace, is the struggle for food among the immature members, in especial, of living races. The death-rate among them measures the number of those who have failed to obtain the food, whatever it be, and from whatever cause.

Two vastly important observations require to be made at this point, before we leave the bare statement of the primary condition for the working of natural selection. They both refer to man, who is the double exception to the normal course of Nature in this respect. It is not true, as Malthus supposed, that food-supply can only increase by arithmetical progression. On the contrary, food-supply is often itself a matter of the growth of living species — say, of rice or wheat, or sheep or rabbits. Under suitable conditions, such living species exhibit the tendency, already proclaimed by Malthus for the case of man, to multiply in geometrical progression. Now, man is the master of other species. He can set them going in new conditions, when and as he pleases, and so create his food-supply.



DR. ALFRED RUSSEL WALLACE

Secondly, he may and does control his own birth-rate, as no other living creature does. It follows that the first condition for natural selection is not satisfied in many illustrations furnished by man. The ideal illustration of what Malthus did *not* reckon with is furnished by Australia, where such food-supply as the rabbit, thanks to man, is increasing in geometrical progression, and where the human population is scarcely increasing at all. It was necessary, in the interests of just statement, to interpolate these two notes on the Malthusian proposition; they teach us that man may be an exception to the very state of things which Malthus asserted about man especially, and they prepare us to understand that, perhaps nine times out of ten, when people talk about natural selection in the case of man, they are using words without knowledge.

In the sense in which the word "natural" is used in Darwin's phrase, to mean mechanical and automatic, man is super-natural, and may at any time, if he chooses, totally reverse the state of things, as to growth of population and food-supply respectively, which Malthus predicated.

It has often been wondered why Malthus, having discovered over-production and the "struggle for existence," should have stopped there, when apparently but one obvious step was required for him to see and assert the consequences of the struggle—that the fittest must survive. But the reason why Malthus stopped short is evident. He was not a naturalist, but a clergyman. He was not familiar, as were Darwin and Dr. Wallace, when their time came, with the two great facts called heredity and variation. And those are the two conditions which natural selection requires, as we shall see. Spencer, in his turn, came to the problem of evolution. But he was not a naturalist either. His training was in engineering. The facts of heredity and variation were not known to him at first-hand, any more than to his clerical predecessor.

But Darwin and Dr. Wallace were, above all, naturalists. From their earliest years they had the passion for collecting which is characteristic of the born naturalist. When scarcely more than an infant, Darwin was collecting, comparing, cataloguing, gloating over shells and beetles and butterflies and seaweeds, and so on. Now,

two tremendous facts steadily impress themselves upon the naturalist. They are, first, that living things run in species or kinds, or types, in virtue of the fact that offspring are like parents. Beetles beget beetles and not acorns; cows beget cows, and not cabbages. This is, of course, the fact of heredity, which seems fairly obvious when thus stated, but which many sapient people are still found to deny. Of course, they do know that oaks beget acorns, and not apples or antelopes, but somehow they had not quite grasped that this is heredity. But of course it is heredity; and on closer inquiry we find that certain kinds of apples beget similar kinds of apples, so that heredity applies not only between species, but within species.

However, though "like begets like," it never begets *exactly* like. There are little differences, and sometimes great differences, as well as great hereditary resemblances, between parents and offspring. This we call variation; and for the present we may contrast it with heredity as a kind of opposite, though we shall see later that this idea of heredity and variation as opposites is only a rough-and-ready one, which deeper study qualifies. Meanwhile, we understand that the first-hand observer, the born naturalist, like Darwin or Dr. Wallace, would be familiar with the fact of variation, even from the age of four or five, when gloating over shells or any other products of life. You cannot put two shells of the same kind together in a tray without seeing, if you are really looking at them, that they are very like, and that they are not exactly like.

HOW THE CATERPILLARS OF THE V-MOTH FEIGN DEATH AT THE APPROACH OF DANGER

Here, then, is the answer to the frequent discussions as to Malthus and Spencer missing what they came so near. The first-hand students had a vital grasp of the three great facts, over-production, heredity, and variation, which had only to be thought about for the theory of natural selection to form itself. The theory asserts, in the full title of Darwin's great work, "The Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life."

First, there must be the struggle. No struggle, no selection. Given, then, the struggle, which depends upon over-production, the factor we have called variation asserts that some of the strugglers will be natively endowed with advantages over others. They will be a little fleeter, or keener-eyed, or sharper-toothed, or stronger-stemmed, or more profusely leaved than their fellows. Or, in the sand of the desert, under the glare of the sun, their coats will happen to be the best match to their surroundings, and therefore the lea-

visible, an advantage either to the stalker or the stalked.

Instances are infinite in number. But in every case it must be that, given a fair field and no favour, and given that only some can survive, the survivors will be the fittest. Foolish critics have declared that, when Darwin's theory is properly examined, it means nothing more than the survival of the survivors. It must require some hardihood to utter such puerilities as that. The survival of the survivors is a necessity of thought. Darwin's theory tells us who the survivors will be: they will be those who are best able to survive, those who are best adapted to the conditions in which they are found—in short, to use Spencer's excellent term, "the fittest."

But so far we have only invoked two of the three factors which we stated to be essential to the working of natural selection, namely, over-production involving struggle, and variation among the strugglers. But we said that heredity was essential also. And so it is, for the offspring of the fittest who have survived inherit their parents' fitness. Thus the next generation will start from a new average, so to say; and while some of its members will be more fit than others (owing to variation again), the whole of the next generation will be fitter or better adapted, as a whole, because, by our theory, it inherits the fitness characteristic of its parents, who were the survivors from the generation before.

CATERPILLARS AND MOTHS THAT MIMIC STICKS
The upper picture shows two stick-like caterpillars of the Purple Thorn moth. The lower picture shows two Buff Tip moths at rest, when they resemble broken bits of stick.

This is the simple theory with which Darwin shook the world when he published his masterpiece in 1859. Half a century later, its publication was commemorated by great ceremonies at Cambridge, and by the publication of a magnificent volume, to which the most illustrious biologists of to-day contributed a series of chapters discussing the relation of the Darwinian theory to the most advanced knowledge of our time. No careful student of that volume could fail to perceive how far we have indeed moved on from the position which Darwin won for us, and how different—in the most essential matter of all—is our estimate of the theory of natural selection from that which was put upon it, never by Darwin himself, nor by Herbert Spencer, but by all Darwin's followers, from Huxley, now gone, and from Professor Ernst Haeckel and Professor August Weismann, still living, downwards.

We have already seen how Spencer aided the Darwinian theory by inventing the term "the survival of the fittest," which Darwin gladly adopted, and which is, perhaps, the most famous phrase invented in the nineteenth century. In his masterly and constructive criticism of Darwin's theory, notably against such critics as the late Lord Salisbury, Spencer pointed out that, given the three necessary conditions

which we have described, the theory of natural selection answers to his famous description of the ultimate test of truth. The last test of truth for finite man is that the opposite of the proposition asserted shall be inconceivable.

If the laws of our reason make it impossible for us to conceive the opposite of a statement, that is the furthest we can go in demonstrating its truth. We can readily conceive, for instance, the opposite, or negative, of any part of the law of gravitation; that is not one of the most certain truths at all, true though it may be. But we cannot really conceive the opposite of the law that "nothing is made from nothing," the law of the conservation of energy, and we cannot conceive the opposite of the law which asserts that, in a life-and-death race for food, the runner who is fittest to get there first *will* get there first. Thus the law of the survival of the fittest, like the law of the conservation of energy, is one of those which are as certainly true as anything can be, because we cannot conceive their opposites.

And no one who has a right to an opinion now questions the truth of the law of natural selection, or the survival of the fittest. Everyone is bound to see that, wherever the conditions obtain, the law must work. Further, we must all agree that this law explains adaptation, or, rather, as is just beginning to be seen, explains the absence of non-adapted species. We see that natural selection is the stern judge before whom all aspirants to existence have to pass. If they are challenged by other aspirants, better adapted to the conditions of the environment, then, inevitably, the best adapted must win. This is a necessary process, wherever the conditions obtain, and they almost everywhere and almost always do obtain.

Thus there is a salutary process almost always at work, which is ever judging and shaping species. All the forms of life we know are thus the survivors, in a competition which goes on from generation to generation, and which is incessantly weeding out those who were and are less qualified to win. This is Nature's competitive examination for life, with the privilege of reproduction as a prize for the successful; and its consequence is always to increase the adaptation, fitness, viability, of living species, while little record or none remains of the innumerable hosts who have been worsted, sooner or later, and who, seeking to be feeders, have been condemned to the humbler function of food.

AN EXAMPLE OF OVER-PRODUCTION—A LEOPARD MOTH WITH A BATCH OF ABOUT 1000 EGGS

"Sooner or later," we have said; and nothing in this theory is of more importance than to realise that this is an examination which is always going on—except for the abnormal case of man, as may

sometimes appear. Nature gives no final verdict. Past success, high qualifications at such and such a time, and a brilliant record since—these are absolutely nothing to her. The question for every living species and every individual thereof is: Can you live and beget *now?* It is of no use for the species to say that it has existed since the Silurian age unchanged, or for any portion of it to say that it beat another portion at Waterloo. Natural selection looks not backwards, but forwards, and judges the present accordingly.

A point of relatively small importance from the standpoint of organic evolution in general is worthy of note here, before we pass on to ask the searching question that remains. It is that natural selection, as asserted by Darwin, is mainly between members of the same species, and only subordinately between the members of one species and the members of another. In brief, it is intra-specific rather than inter-specific.

The importance of this distinction lies in what we seek, by natural selection, to explain. If we wish to explain the balance between species, their mutual relations, and their adaptation to one another, then it is the struggle between species and species that we must invoke. But it is adaptation in general, the fitness of each species for its surroundings as a whole, that is the chief problem of organic evolution, and the only kind of struggle and selection capable of explaining that is the selection within a species, ever excluding the less adapted, selecting the better adapted, and so, at last, shaping the type of the species into the marvellously adapted forms that we witness on every hand, whether in the animal or the vegetable world.

THE ICHNEUMON FLY THAT HAS DEVELOPED A VERY LONG OVIPOSITOR

In the struggle for existence this insect has become especially adapted to lay its eggs in the bodies of caterpillars lying beneath the bark of a tree, its young being born in and feeding on the bodies of their hosts.

But, on the other hand, we are not to suppose that species are adapted to suit each other, for the sake of each other. Each species for itself is the rule. Individuals may, and do, exhibit characters which do not serve themselves, but those of other individuals of the same species. That we see repeatedly, from the sting of the worker-bee, which exists for the hive, and the employment of which involves her own death, up to the breast of the mammalian mother, which serves herself not at all, but the race indispensably.

On the other hand, we may search high and low, but we never find any character of any species existing *in order to* serve any other species. More than fifty years ago Darwin declared that he could find no such instance, and none has been found since. We may think the grass was made for the ox, or the grass and the ox for ourselves, but we are deluded. Grass is made for the race of grass; eggs for the race of birds; cows' milk for calves, and so on—whatever tricks one species may play upon another in the search of food.

In our statement of the theory of Darwin and Dr. Wallace, we must especially observe that it leaves on one side the possibility of adaptation through the inheritance of characters acquired by parents. Lamarck said that the giraffe stretches its neck by use—or, rather, the ancestors of the giraffe did so—and that the successive offspring acquired in this way their adaptation to their particular mode of feeding.

The theory of Darwin says that giraffes are born, some liable to be taller, and some shorter. Where food is scarce, and tallness favours feeding because it makes the leaves of trees accessible, tallness will be naturally selected in successive generations, and so the giraffe we know will be produced. The two explanations of evolution are fundamentally different, and must not be confused. We only need to note further that Darwin accepted the view of Lamarck as contributory to the origin of species, where it is applicable; but modern Darwinians totally deny the possibility of the "inheritance of acquired characters," and call themselves Neo-Darwinians, or new Darwinians, more Darwinian than Darwin, "plus royalistes que le roi."

Finally, we must note the essential feature of this theory, which is the accidental character of the variations that make evolution possible. The variations are regarded as absolutely fortuitous, to use the accepted term. Some are in one direction, some in another; the only law which governs their production and occurrence is the law of chance. They are thus like the shots round the bull's-eye of a target, distributed all round it, denser nearer it, and ever fewer and fewer the further they depart from the average or type of the species. Natural selection then chooses among these random variations, according to their relative fitness.

THE STING OF THE WORKER-BEE

In this photograph the sting of the bee is shown to the right of its sheath, magnified many times.

This is the crucial moment of our whole inquiry. Darwin himself never made the mistake of consciously supposing that he had accounted for the production or *origin* of the variations which natural selection selects. But in naming his book "The *Origin* of Species," and in the use of the term natural selection, he inevitably made possible, if not for himself, at any rate for others, a conception of his own theory which will not hold water. If species arise in certain variations, then the problem of the origin of species is the problem of the origin of those variations, those new forms of life, which natural selection then selects. The theory of natural selection therefore explains the fixation of species, the non-persistence of the non-adapted or the misfits, and the survival of the well adapted or fit. But it tells us nothing as to the "origin of the fittest." In short, while it contributes to every problem in biology, and solves many, the one problem, above all, which it does not illuminate, and to which it makes no contribution whatever, is the problem of the *origin* of species. The fixation, the adaptation, the survival of species—all these the theory of Darwin and Wallace illuminates, but of the origin of species it tells us nothing at all.

The misunderstanding, which is gigantic, and which endured, even among the highest authorities, for something like four decades, was due to what we have already hinted at as the most serious objection to the phrase "natural selection." The phrase gives a positive colour to what is essentially a negative process. The proper name for the process called natural selection is natural rejection. Undoubtedly, to choose is simultaneously to refuse, to select one of two things is to reject the second. But the process, as it actually occurs in Nature, is admittedly a negative one; it consists in the persistent extinction of the less-adapted, a negative process which involves the positive corollary that the more adapted are not extinguished.

The distinction between the two terms is not merely verbal, nor is there any better instance of Bacon's argument about the deceptive influence of words upon the understanding. If natural selection had always been thought of as what it is, namely, natural rejection, no one would ever have

supposed that the phrase somehow explained the origin of species. The rejection of anything does not produce anything else. *Nor does natural rejection produce the forms which it spares.* The problem of the origin of species remains untouched; and though Darwin's work contributed to everything else, it contributed nothing to that.

It is no easy matter to persuade those who have not been through all this work for themselves that Darwin's theory retains an indispensable value, and that his work and his fame can never be dimmed. Yet such are the facts. Natural selection, and the other forms of selection, are unquestionable realities. Between them they have the most potent influence in moulding and controlling all the forms of life, everywhere and always; and never was the study and appreciation of them more necessary than at the present time, when students are attempting to erect, largely upon the foundation of biology, a new science, which they call eugenics. Both on theoretical grounds, and for the momentous character of their practical applications, the forms of selection must be studied more closely than ever—not least that which Darwin later described and to which he gave the name of sexual selection, for the consequences of this process may be stupendous. But the first step towards any possibility of really appreciating the significance of the idea of selection in biology assuredly is to perceive that selection selects—or, rather, rejects—but does not create. The problem of the "creation," "origin," "evolution," of what selection selects is still our problem to-day.

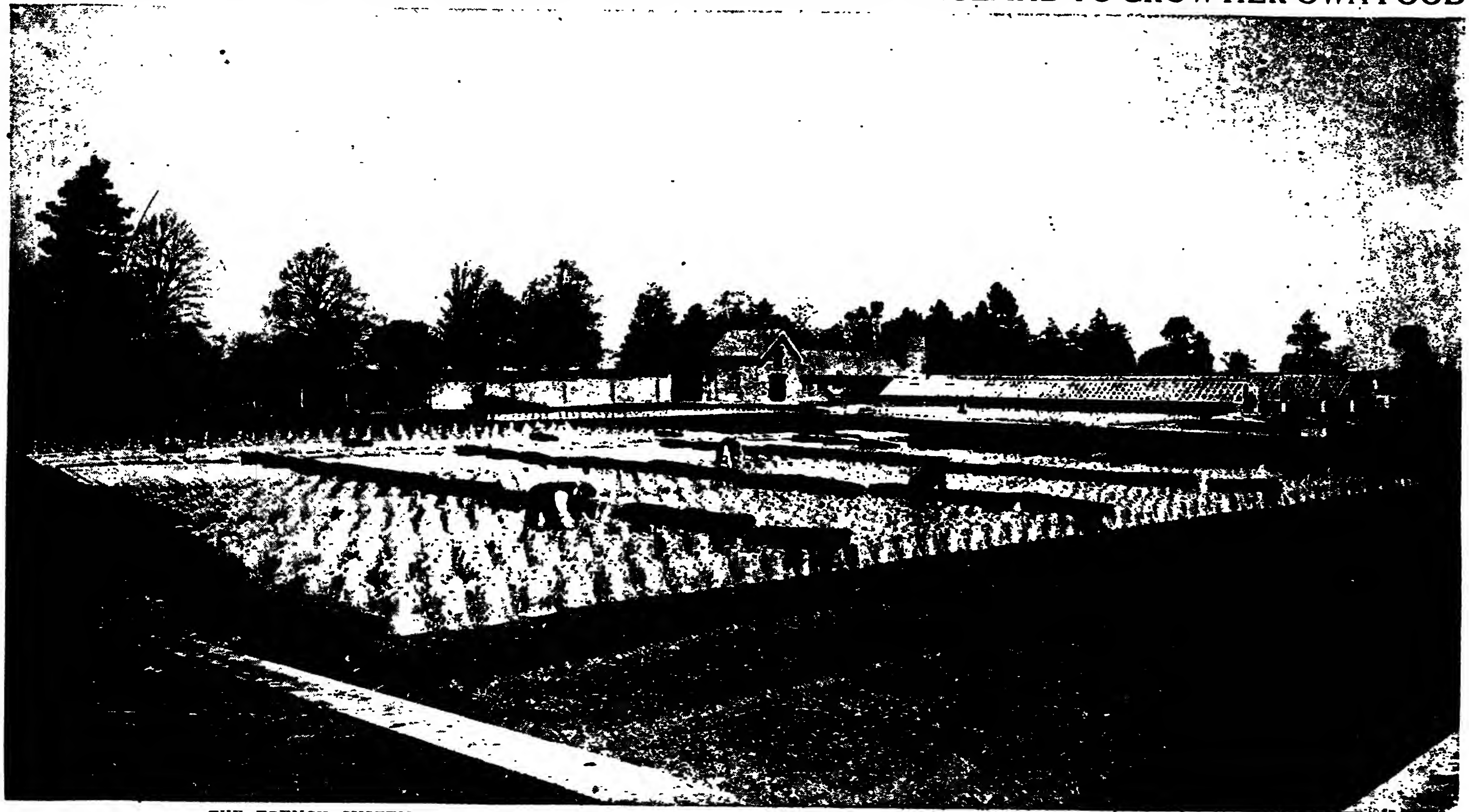
PROTECTIVE MIMICRY ON THE SEA BOTTOM

These sea-snails from the West Indies cement lime and stones to their shells

Certainly the neo-Darwinian answer to it must be abandoned. This answer, expressly excluding any of that transmission to offspring of parental modifications, in which Darwin himself believed, declares that absolutely random variations, conveniently called "spontaneous," and without any tendency, bias, or predilection in any direction whatever, have furnished the material which natural selection has fixed in the form, say, of the eye, the internal ear, the instincts of the worker-bee, and countless myriads of other structures and capacities of living things. Not even so imposing and persuasive a word as "spontaneous" can continue to hypnotise us into the view that nothing remains to explain—except that heredity, so to say, is rather a bad shot, and that its imperfections, called variations, and accumulated from the time of the microscopic one-celled animals, and plants, and from forms earlier still—have given us the economy of the bee-hive, and the nervous apparatus of which "Hamlet" and the book of Isaiah were products. The mechanical-mathematical theory of organic evolution has left the Prince of Denmark out of the play.

The magnificent analysis of Professor Henri Bergson, in the first chapter of his "Creative Evolution," has furnished, from the side of logic and philosophy, an exact complement to the work on variation which was begun by Mendel, and is now remaking our theories of evolution. Prof. Bergson has seen a new argument, after all these decades, which has occurred to no one before, and which strikes at the very root of the mechanical theory. He points to the eye in vertebrate animals, with its marvellously delicate, complex, and exactly suitable parts. It is sufficiently difficult, he declares, as Darwin himself declared, to believe that this amazing organ has been mechanically evolved by the accumulation of accidental variations which natural selection could choose from. But an eye of closely similar structure is found in some molluscs, animals of radically different structure and belonging to an utterly different branch of the tree of life. The theory of natural selection, in asking us to believe that the same long series of happy accidents has occurred independently along these two lines, strains belief to breaking-point. It begins to be evident that there is something called Life, which responds to the touch of light, and evolves the seeing eye; something, as Bergson says, "of the psychological order," immanent in all living things, low as well as high, which feels and strives and achieves, and which made the eye, as man made the microscope.

INTENSIVE CULTURE THAT IN THE FUTURE MAY ENABLE ENGLAND TO GROW HER OWN FOOD



THE FRENCH SYSTEM OF GARDENING UNDER GLASS AS ADOPTED AT BARROW-ON-SOAR, IN LEICESTERSHIRE

This picture is reproduced by courtesy of The Cloche Company; those on page 1291 by courtesy of the Agricultural Electric Discharge Company, Limited; and those on page 1293 by courtesy of Dr. J. H. Priestley. Others are by Mr. J. J. Ward, Messrs. Hinkins and Son, and Messrs. Fermes and Chareux.

THE DEFEAT OF THE SEASONS

Quicker Growth and Greater Productivity Secured by Modern Methods, the Use of Electricity, and Glass

THE MIRACLES OF INTENSIVE FARMING

Anyone who lives in England with his eyes open will know that the times and seasons of flowers are much less regular than is usually thought. Many plants, if there is any temptation from the weather and climate, will put out flowers even in winter. In almost any winter that is at all open you may find the charlock—that wild-mustard plant which is such a trial to farmers—flowering profusely in the fields that have been left unploughed. In the chalk country you may see a hillside quite yellow with the bloom. Now, what we may call the proper time for charlock to bloom is the early summer, but it answers to the state of the atmosphere rather than the date on the almanac.

This is an example from Nature's way in the fields. Many more startling instances may be taken from man's way in the house. A very remarkable fact about bulbs, such as the snowdrop, or tubers, such as the potato, is that they cannot be forced into premature or unnaturally early bloom. Of course, very favourable conditions will make them shoot rather earlier than unfavourable or even normal conditions. But it remains true that the bulb must go through a regular course of maturing within itself before its life is made manifest by new growth.

A discovery of the two facts that the bulb could not be forced, and yet would flower rapidly as soon as this maturing process was complete, has enabled men to produce flowers—for example, of the lily of the valley—at any time they choose. They freeze the bulb instead of forcing it. This freezing arrests all the processes of life, but does not destroy them. As soon as the cold is removed, the bulbs grow and flower with the speed of plants in Northern lands, where the ground is covered with bright flowers within a few days of the disappearance of the snow. Spring comes then in a flash, at the first flash of the eye of the prime magician, the sun. By this aid the natural seasons may be said to be quite defeated: spring plants may flourish in summer or autumn or winter.

Between the semi-natural blooming of the charlock in winter and the quite unnatural retarding of the lily of the valley by florists lies a middle marvel, accomplished by gardeners who try to defeat the seasons for the sake of providing food. They have accomplished miracles; and it is generally believed, though little is as yet proved according to the standard of the laboratories, that further miracles are shortly to be wrought.

In every part of the world men of science are experimenting with electricity in relation to plants. In Worcestershire are to be seen quite a number of fields over which electric wires are stretched. The experiments are due, in the first place, to the initiative of Sir Oliver Lodge; and there is very little doubt that the effect of the wires was to stimulate the plants to stronger and more rapid growth. It had been stated that plants grew rather better under telegraph wires, but there is little reason for believing this. The Worcestershire experiments have not had any very startling success, though certainly strawberries, if no other crop, have been improved by the wires, but enough has been done to make the experimenters feel sure that there is a future for this method of stimulus.

In Germany, again, very many experiments have been made with electrical wires, and results of a very striking character have been reached. There two or three methods of fixing the wires have been tried. In some of the latest the wires have been run in the earth, but it is now generally held that the best results come from wires

stretched in the air, but at no great distance from the plants. This method, so far as can be seen as yet, not only helps to bring on the plants earlier, but to give them a certain additional vigour which helps them to resist disease and to grow both larger and healthier. The Government has concerned itself with this electrical treatment, and many people believe that one day it will become general.

But one of the most remarkable series of results was recorded by an English lady from a number of experiments made in 1910 and 1911. She tried the effect of treating the soil with a succession of currents of electricity; and the immediate result, so far as the tests went, was greatly to multiply the number of those bacteria which chiefly produce the fertility of the soil and make possible the growth of the plant. That electricity can help to defeat the seasons and increase the energy of growth seems certain. It has yet to be discovered what sort of currents will best serve, and whether the method is too expensive.

Curious Experiments in Stimulation of Growth by Means of Electricity

Other experiments, which all tend in the same direction, have been made by putting both seeds and plants in direct contact with the electricity. Seeds laid on a plate on which damp earth was placed certainly began to germinate, or to show movement in the germ, within an hour's time. It is probable that this "miracle" was due not to proper germination or growth, but to the breaking of the seed; and there may be some such explanation of the astonishingly early growth of some wheat which was grown in Essex. It certainly came up very much earlier and was sown very much later than other wheats; and it may be true that this earliness was due to the treatment of the seed by electricity.

Again, some very curious effects were discovered at the Royal Botanic Gardens in Regent's Park, following the direct application of electricity to the leaves of certain hothouse plants, and also from the burning of electric light. Nothing has been published abroad of these experiments, which were discontinued owing to the death of one of the experimenters; but more is to be done, and enough was done to prove the fact that the plants were stimulated by more light, just as the tropical birds in the Zoo were made healthy and longer lived by artificially prolonging hours of daylight.

Within that "year wonderful" of 1911 it was shown that electricity had a marvellous effect in preserving all sorts of agricultural products. To give three examples, water, milk, and the tobacco leaf, when subjected to certain electrical treatment, are said, under good evidence, to have been freed from evil presences, in the shape of bacterial fungus, which prevented them from keeping sweet or wholesome for any long period. That perhaps lends some ground for hoping that this strange force may be applied with success also for these purposes.

The New Experiments in the Encouragement of Plant-Growth by the Use of Coloured Glass

Other experiments have been and are being made with various colours. It is probable that certain plants at certain stages and at certain times of the year are very much encouraged and purified by blue and green rays. It is very apparent to the eye how very differently plants have grown according to the colour of the glass put around them. It is true that these and other experiments are yet in a very early stage, and it is not safe to assert that any of them are certain to increase crops or ensure the defeat of the seasons. But we live at a time when science has found the right line of endeavour, and is moving very rapidly, like an express train, along "the ringing grooves of change." We all feel almost as if we should, by standing on tip-toe and straining a little, see over quite a new country and into new life.

For the first time science has begun to apply its energies to that first and last, most elementary and elemental, industry—the culture of the land; and we may at least nourish a fair expectation that, within a short time, at least as great things will be done for agriculture as have been done for other industries. Among these benefits electricity may play a great part. It may cause quick growth both of the seeds and of the full-grown plant; it may assure good health and freedom from the hundred diseases that spoil crops; it may help to make us independent of the accidents of the seasons.

The Wonderful Part Played by Glass in the Agriculture of Recent Years

These things belong to the future. In the past is one discovery which has already made gardeners more or less independent of spring, summer, autumn, and winter. Glass is perhaps the most wonderful substance ever manufactured by man. It admits light, it admits heat, but it admits no air, and is proof against many chemicals which would devour iron and steel as flame

devours coal. Everyone is familiar with the greenhouse or conservatory, and, indeed, the garden frame, but it is only now, in England at any rate, that the possibilities of glass are being understood. The geraniums that gleam in a thousand cottage windows like a cheerful hearth are one small example of the influence of glass on plants. But it is on a scale much larger even than the large greenhouse that glass is being used, and will be used. The most wonderful cultivation in Europe is to be seen in the island of Guernsey, along a stretch which has been called the Valley of Glass.

Something of the sort is to be noted, though the form of it is very different, in England. Any traveller by the Great Eastern Railway will have seen the acres of glass and brick houses, increasing year by year, from which a vast store, especially of tomatoes and cucumbers, are sent up to London. The yield from these acres is colossal, whether we reckon it in weight or number of fruits. It was said earlier that Essex could supply half London with bread. If wheat could be cultivated as those tomatoes and cucumbers are cultivated, it could supply all London. This, no doubt, will not be done. It is better to grow wheat with less cost on the wide plains of Canada and Siberia, but the method shows how far glass may help man to get plentiful food of fine quality off small plots.

The great enemy to these glasshouse gardens is fungus, of which there are several venomous varieties. If, as some people hope, electricity can be practically employed to kill those diseases, the industry will double itself or treble itself within a very short while. An English farmer to-day would laugh anyone to scorn who would dare to suggest that glass could be used in the fields, yet what may be called field-glass is to be seen in several places in England. Strawberry growers in Hampshire now often use light and cheap glass frames of a structure suitable for covering wide spaces. In some cases strips of glass are used which are merely leaned up against planks. In Worcestershire you may see quite elaborate greenhouses erected on what otherwise seems an ordinary farm; and from these houses are sold very large quantities not only of fruit such as strawberries or grapes, but good store of lettuces and peas and other vegetables. You also see about the fields queer conical "hats" of glass, usually set over melon plants. England would be in many ways a very excellent climate for growing crops of great variety if it were not for one short period which, above all others, has to be defeated by all who grow fruit. About the middle of May comes, as a rule, a sharp frost. In Germany, which suffers hardly less than England, the frosts are said to come on the festival of "three icemen," three saints whose holy days follow successively from May 11.

RETARDED LILY OF THE VALLEY ROOTS AND THE RESULTS OF FOURTEEN DAYS' GROWTH

The defeat of that frost would mean very many thousands of pounds and much more store of food for England. In the fruit country it is being defeated, with the help of better weather prophecy, by means of "smudges"—that is, many little fires burning material that sends up a thick and heavy smoke sufficient to protect the tender blossom, that else would

be blackened in the centre by the frost and presently fall useless to the ground. As the period over which frost is to be feared is very short, and it is usually not difficult to foretell its coming, this particular defect of the season should be easy to overcome in the end.

An apparatus has been devised to announce the coming of frost by ringing an alarm. A thermometer is set in connection with an electric apparatus so that directly it falls to freezing-point an alarm is rung, and the fruit-grower—such is the idea—goes out and lights his "smudges." These things are not, of course, usually done in practice, but they show in their degree the advance of man's control over conditions.

The French, who have been and still are the pioneers of the world in many respects, have shown the world the most thorough system yet devised of defeating the season. The original idea of this system, known as the maraicher, was to anticipate spring largely in order to enable the gardener to receive greater prices for his produce; but the effect of the system is to prove the enormous capacity of the ground for production, and the vast energy of growth in plants which will enable them to come to maturity within a few weeks. It has been proved again and again that by the French methods at least £600 worth of food can be gathered from an acre; and nearly all the crops are more or less out of season.

These French gardeners have no doubt made use of a deep secret of growth. They give the ground this astonishing capacity for producing crops by mixing fresh manure and old, well-rotted manure in very definite proportions; and it is now thought by some investigators that the effect is to give ideal conditions for the multiplication of those beneficent bacteria of the soil about which much has been written. But, however this may be, the practical marvel of these French gardeners—whose methods have been copied by the Dutch—are visible enough. They can be seen in England, too, where some fifty gardens of this sort have been established. Beyond all dispute, as many as six crops in the year can be gathered off one plot. A number of these are grown simultaneously; and this idea that you should grow three or four crops all together, cheek by jowl, most attracted the old-fashioned gardener.

The French gardener usually sows four together. He simply sows broadcast radish, lettuce, and carrot seed, and very often also sets cauliflower plants. All these start life together under the same frame. But they grow at different rates, and the crops are gathered successively, the first of them coming before winter is quite out, and the last before the summer is old. The ground is then free to grow out-of-door crops; the hotbed has become a cool bed, and the open air is substituted for glass. It is at first incredible when one hears the weight of produce thus brought to the market, but it is not at all incredible when you see these packed frames and reckon the number of men and women working on the acre.

The secret is partly one of soil, partly of glass. The soil must consist largely of rotted vegetable matter, and it must be

THE CLOUDS OF SMOKE THAT PROTECT THE VINEYARDS OF FRANCE FROM THE MID-MAY FROST

ELECTRICAL STIMULATION OF PLANTS

The pictures above show the apparatus used at Bitton, near Bristol, for the generation of electricity, the wire conveying it, and the greenhouses, where it was applied to stimulate plant growth.

warm to supply all this tangle of roots with food. But they grow quickly, in part because they are kept very close to the glass; and this nearness of the glass to the plant is one of the distinctions of the French garden. Frequent transplantation is another. The art is a difficult and a delicate one. If too little air is admitted into the frames, or the sun is allowed to develop too great a heat, or the mats are not drawn over the frames on a frosty night, half the labour is wasted.

The system is costly, too. It needs an enormous supply of water and of manure, and usually the work of carrying is done by trucks on a little line laid round the beds. The French use both frames and cloches or bell-glasses. The Dutch use only frames, but have clear glass sheets in place of small frames so that the light may fall as evenly as may be on all the plants.

Again, the work is very laborious, and the maraicher gardener seldom rests. It may or it may not be a desirable thing to grow food in this way. The Dutch gardeners are perhaps as fine a type and as healthy and happy a set of men as could be seen, but this cannot be said of all the Paris gardeners.

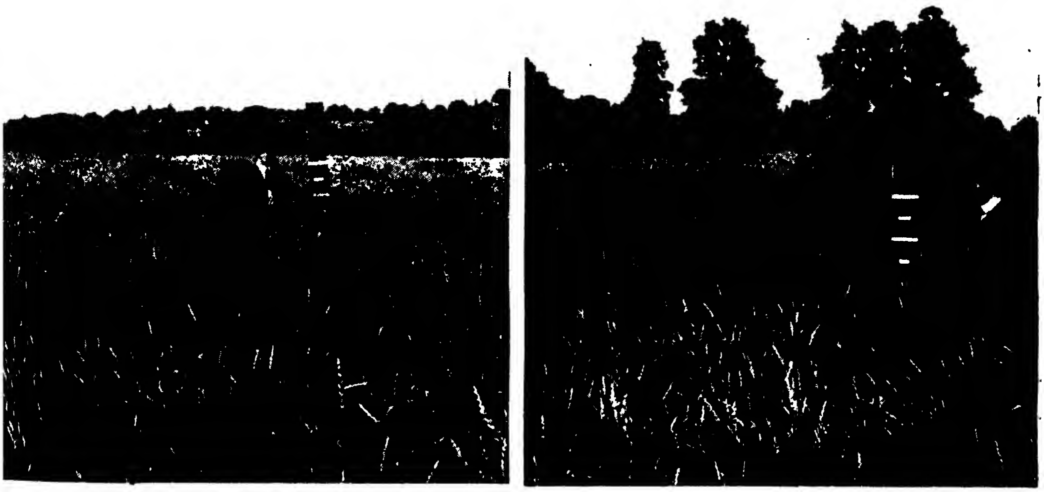
But the importance and interest of the French garden are beyond all question. A comparatively few gardens in the outskirts of Paris and in Holland supply England and a great part of Europe with early vegetables; and while this can be done on any system, the fact is important in considering the vital question how the human race is to be fed. It is also important in the natural history of the plant.

A point in this sort of culture of which very little notice has been taken is the rapidity of growth in the vegetables and the effect of it on the nature of the food. But it should be a well-known fact that the faster a thing grows the better it is to eat. The one part of a vegetable which it is quite impossible to digest is its so-called cellulose: in other words, its stringiness. A lettuce that has grown to maturity in six weeks is almost free from cellulose; and one reason why the French have spent such energies on this art, which is almost a science, is their peculiar appreciation of the wholesomeness of the French garden produce. As the general art of culture advances men will probably use many means to make growth more rapid. They thus secure more palatable and digestible food; and they clear the ground in time to use it again. The French gardener treats his acre as a factory; and he likes to keep it working at high pressure, and "turning out stuff" continuously. He has a horror of fallow ground, and towards his ideal all cultivators will probably move in a smaller or greater degree.

THE MATS PLACED OVER GLASS FRAMES IN A FRENCH GARDEN TO WARD OFF THE FROST

Europe has moved towards that ideal at a much greater rate than is usually thought. At the end of 1911 an American specialist, who had travelled throughout Europe at the instance of the American Government, issued a report in which he asserted, on good evidence and irrefutable statistical figures, that the agricultural output of Europe had increased within the last generation by over 70 per cent. The supposed "worn-out soils" of Europe, of which Americans often speak, have been made new again, and produce vastly more than any of the virgin soils of the American continent. The American traveller attributed this enormous improvement to the cultivation of one plant—the sugar-beet—a sort of mangel, rather resembling a parsnip, from which a great proportion of the sugar supply of the world in extracted. The careful cultivation, entailing the absolute destruction of weeds, the amount of manure necessary to bring the crop to perfection, the aerating effects of the roots of the beet, which penetrate deep, and, lastly, the scientific art of cultivation which the crop induces are given as reasons why such astonishing improvement has gone with the cultivation of beet. It is more than probable that it will soon be cultivated in great quantities in America. But other things than the beet have produced this increase in the industry of the land.

Men of science have begun to co-operate with men on the land; the nations have come to the help of the individuals. New and improved seeds, new and improved machines, inventions, and discoveries, and the necessity of feeding larger populations; perhaps also the growing sense that national prosperity and health depend first on agriculture—are all joining together to the end of more intensive cultivation and the raising of the art and craft and science of making and taking harvests. If the fields of Europe have grown rich to this extent, what shall be said of the gardens, private and commercial, small and great, or of the glasshouses or the nurseries? The different nations of Europe have improved in very different degrees, and the different Governments have shown varying degrees of interest. Belgium is the most remarkable in many ways, because the soil is poor; and yet it out-produces—if the word may be used—all the virgin soils of the West by 50 per cent. or more; and English acres cannot compare with it either in the amount of stock or the weight of crops. Denmark leads the world in organisation, and in the effective co-operation of the Government with farmers and small-holders. Sweden is supreme in its agricultural colleges, and in the production of new seeds and roots. Germany has performed marvels in the reclamation of waste land and in the growing of certain crops, especially potatoes and beet. The French have reached the very highest pitch of high farming and intensive cultivation. In England we have many good farmers and seed-growers, but there is no country in the world where so little is done for agriculture, or where so small a portion of the food of the people comes from their own soil. But a new era is at hand.



A CONTRAST IN THE HEIGHT OF WHEAT GROWN WITH AND WITHOUT THE AID OF ELECTRICITY

FIVE MEMBERS OF THE WEASEL TRIBE

THE INVALUABLE WEASEL

THE PERSECUTED ENGLISH BADGER

THE FERRET—A TRIUMPH FOR MAN'S POWER OF TAMING

THE AMERICAN BADGER

THE OBNOXIOUS CANADIAN SKUNK

The photographs on these pages are by Messrs. W. P. Dando, C. Reid, L. Medland, Douglas English and others.

THE WILY WEASEL FAMILY

A Vermin-Destroying Family of High Value. How Domestication Might Bring into General Use Furs that Now are the Signs of Luxury

WHY HAVE WE CEASED TO TAME THE WILD?

Among the weasel tribe are to be found animals yielding fur that ranks with the most valuable in the world. Wild and unknown lands have been explored in quest of these fur-bearing animals; men have risked their lives and borne terrible privation to secure them, and, incidentally, they have filled up the blank spaces on the map and given the world knowledge of latitudes that might to this day have remained unexplored but for such expeditions. Courage inestimable and energy incomparable have been displayed by the fur-hunters, but not brain.

No man has seriously tried to domesticate one of the fur-bearing members of the weasel family. The Manchurians breed dogs for their magnificent furs, but nobody has dreamed of domesticating the sable. The polecat has been domesticated, and has become the ferret, and the otter has become the fish-catcher for certain Oriental peoples. But man has never regarded the precious sable or the valuable marsh-haunting mink as anything but animals to be slain. Surely a great opportunity has been wasted. It is possible, of course, that the sable might prove infertile, as many other animals in captivity have proved, but that is by no means certain. The ferret is far more prolific in captivity than its wild relative, the polecat. As the sable has been persecuted almost out of existence, owing to the extraordinary demand for its precious pelt, the experiment might yet be worth trying.

By the same token, there might be a good opening for the man with wit enough to domesticate the common British stoat, whose winter coat, in the cold, northerly part of our land, furnishes the valued ermine. And, as our inscrutable laws have convulsed public opinion by the dictum that it is unlawful for the public to fish in river or lake in these islands, it might be worth while trying whether a loophole could not be found by setting the otter to work after the fashion of the wise men of the East.

It has taken the law some hundreds of years to discover that the public has no fishing rights; we might have quite a good time with otters while the law makes up its mind on this new suggestion. Any scheme that could awaken public interest in the animals of this large family, and cause them to be regarded as worthy of attention from others than the man who goes out with his spear and his hounds simply to worry and kill, is highly to be praised. Possibly the ideas of "furs from our home-bred sables," "ermine from home-reared stoats," and "fresh fish for breakfast caught by our own otters" might merit commendation as likely to save the family from complete extermination. The ravages of otter-hounds, and the clamour of those who affect ermine and sable, must be combated by something more systematic than the passing of a fashion if these interesting animals are to be preserved in the scheme of living things.

The members of the weasel family were until recently classified with the bears and raccoons, but investigation of the middle and lower Tertiary rocks of Europe and North America is now interpreted as showing that the resemblance is simply another interesting example of parallel development. As the sea-otter has developed on lines resembling the seal, so the typical members of the family have evolved on a plan resembling that of the bears and raccoons. Men in different ages and in different continents invented the compass, and gunpowder, and the cantilever bridge, unconsciously following parallel designs. Nature, too, utilises one plan for various animals. The family here is a widely distributed one, comprising some seventeen genera and upwards of fourscore different species, of which we can refer to but a few.

At the head of the group come the tayra and the grison, both belonging exclusively to Central and South America. The first matches the otter in size; the grison has more the proportions of the marten. Both frequent hollow trees, clefts in rocks, and the deserted burrows of other animals when setting up house, and both prey upon small mammals, birds, and eggs, and make themselves destructive enemies of the poultry-farmer. A small Patagonian weasel-like animal, the *Lyncodon patagonica*, is believed to be allied to the tayra and grison, though some naturalists hold that the African striped weasel is its nearest kin.

THE OMNIVOROUS BEECH-MARTEN

The typical group of the sub-family Mustelidæ comprises the martens, the polecats, the stoats, and the weasels. They are all long-bodied, short-legged, bloodthirsty carnivores. The pine-marten is one of the few wild carnivorous animals that survive in Great Britain. Although it is not frequently encountered south of the Lake country, isolated specimens are sometimes met even in the Home Counties. Its range extends over a wide area in Northern Europe and part of Asia, and, wherever found, the habits of the animal are unvarying. With a body-length of from sixteen to eighteen inches, it has a tail of from ten inches to a foot, and it climbs with remarkable address both trees and the smooth, perpendicular posts that support the dovecots it delights to raid.

A RAPACIOUS HUNTER: THE PINE-MARTEN

Although mainly arboreal in their habits, pine-martens descend to the ground to prey upon hares, rabbits, and smaller animals. Moreover, they will attack both poultry and lambs. Some years ago, an Irish farmer, who possessed twenty-one lambs, found to his consternation one morning that fourteen of his little flock had been killed. On the following night the remaining seven were treated in the same way. It was before the days of cattle-maiming, or the mystery would have seemed to possess some political significance. And to prevent the growth of suspicion, on the second morning the actual culprits were discovered, returning, gorged with blood from the scene of their sanguinary exploits. They were a couple of pine-martens, which had made a home in the deserted nest of a magpie at the top of a tall tree in Tollymore Park.

The beech-marten is lighter in colour than the pine-marten, and is distinguished by slight structural differences recognisable by the anatomist. It ranges throughout a great part of Europe, Palestine, Syria, and Asia Minor, but has never reached Great Britain. It exceeds the pine-marten in boldness, if not in ferocity; and perhaps its greater size and wider distribution are correlated with the fact that it thrives upon a more varied diet than its congener. While the pine-marten is exclusively carnivorous, the beech-marten has developed a taste for fruits of various kinds, so that it has become necessary, in some parts of the Continent, to spray the trunks of fruit-trees with tobacco-juice and petroleum, the odour of which the animal finds intolerable.

Both martens pay for their keep with their skins. The beech-marten's pelt is that "stone marten" of which we hear, the name being simply a translation of the "steinmarder" which the Germans apply to the animal because, although its home is naturally among woods and trees, it is frequently found among rocks and stones. Although it is not among the most valuable of the furs, the skin of many a beech-marten is worn by unsuspecting ladies in the belief that they are adorning themselves, if not with the finest of sable, still with sable of a sort.

The true sable is, however, not far removed from the marten; and some naturalists wrongly hold it to be simply

a variety of pine-marten, distinguished by the greater length and fineness of its fur. But it is a distinct species. Its range has been considerably limited by the relentless persecution to which fashion has for years caused it to be submitted, and now it has to be sought in the wildest parts of Northern Asia, chiefly Eastern Siberia and Kamtschatka. Mainly carnivorous, it has to eke out existence, during the extreme severity of winter, with a diet of berries. A fine tree-climber, it must find much of its food supply during its nocturnal excursions among the branches; and to this must be due the circumstance that the sable is one of the few animals of high northern latitudes whose coats do not change colour in the winter. But it is its winter coat that is desired, the summer fur being too short to prove acceptable.

Passing over one or two other martens, we come next to the polecats, which, apart from certain structural differences, are distinguished from the former by the fact that while the martens are inoffensive in the matter of odour, the polecats are equipped with a notoriously evil fluid for the confusion of their enemies. The name "polecat" presents an interesting problem to the etymologist. The "pole" or "pol," as it was originally spelt, may be a corruption, it is thought, of the French "poule," a hen, in reference to the animal's weakness for poultry. Or it may have been twisted out of the old English word "foumart" or "foul marten," a name justified by its disgusting odour. The polecat survives in Great Britain, but is so fierce an enemy to poultry and game that it is destroyed without mercy.

In many parts of Europe, in Asia, and in parts of North America, polecats of various species are common. Though they vary in size and colouration, their habits are similar, their defensive odour abominable. To have evolved the ferret from the polecat is a distinct triumph for man. In this animal the offensive scent has been largely destroyed, while, as has been mentioned, the power of the animal to multiply has been increased. It would be interesting to see whether the domesticated ferret, if liberated, would revert to the characteristics of the true polecat. There is little likelihood of the question being answered, for even the long period during which the animal has been domesticated has not removed it from suspicion. It has been kept simply as an aid to the hunting either of rabbits or rats. Like all the members of the weasel tribe, ferrets are incorrigibly bloodthirsty. A couple of them will kill more than a hundred times their number could eat, and their almost insatiable passion for blood must be the explanation. And even the oldest and most experienced ferret must be muzzled before being turned into a rabbits' burrow, or it would remain there to drink the blood of the first victim it chanced to hunt down.

AN EVOLUTIONARY MILESTONE: THE POLECAT, FROM WHICH THE FERRET HAS EVOLVED

The true weasel is, fortunately, still fairly common in Great Britain. Were its

numbers still larger we should hear less of plagues of rats and mice. It is the best mammalian protection against these pests that we have. For its size it is quite one of the boldest and most pertinacious hunters in the world. No hole is too small for it to insinuate itself into in pursuit of a rodent. It will at times attack rabbits and hares, and young or sleeping game-birds. But the damage that it does in this respect is infinitesimal contrasted with the value of its services in respect of rats and mice; and the man who slays a weasel ought to be pilloried with the inexcusably blundering man who kills an owl.

If rats do £14,000,000 worth of damage a year in the United Kingdom, as is alleged after careful computation to be the case, a rigorous campaign against the weasel-slayer should prove a good investment for the farmers of this country. The animal has a widespread distribution throughout the whole of Europe, Northern and Central Asia, and the northern part of America; and in the colder parts of its habitat changes its coat to white with the first flurry of the winter's snow. The alertness and acuteness of the weasel are proverbial, but it is not impossible to catch one asleep: Sir John Millais succeeded, finding and painting one as it snoozed in a crannied wall.

The stoat has a sort of unwritten place in the British constitution; the peerage and the judicial bench would be ill furnished indeed without their ermine. The fur upon these robes is simply the winter dress of the stoat, which, in Scotland and the more northerly part of its range in Britain, in America, Europe, and Asia, always becomes white with the appearance of snow. Slightly larger and more powerfully built than the weasel, the stoat attacks larger game, and is really more to be feared by the poultry-farmer and the game-keeper, though as an inveterate enemy of rats, mice, and other "vermin" it thoroughly merits its place in any civilised country where these rodents are destructive of property. Ermine fluctuates in value, as is the case with all furs, but the craze for this particular adornment, a year or two ago, must have made it obvious that the domestication of the animal should possess commercial possibilities. The stoat can be domesticated, as has been proved with excellent results in America, where these animals have "ferreted" as intelligently as the best of tamed polecats.

To find the next member of the family, the glutton, or wolverine, we must now betake ourselves to the northernmost parts of Norway, Sweden, and Russia, to Siberia, to Canada, or to Alaska, but anciently it abounded in England. It is the largest of the weasel tribe, equalling, in the adult stage, a small bear, and differing from the rest of the tribe in that it stands fairly high upon the leg. Man has no use for the glutton, but the glutton has a use for man. The trapper is the glutton's best provider, and it follows in his steps as assiduously as the jackal follows the lion. He sets miles upon miles of traps; the glutton follows, and eats or buries every animal that is caught. Such are its skill and cunning that it is almost impossible to trap the animal itself; it shows an uncanny guile in eluding the artifices of the despairing trapper. It preys upon all small mammals, and will pull down a wounded or sickening deer.

AN ENEMY OF THE BEAVER: THE GLUTTON OR WOLVERINE

If we admire the admirable winter lodge of the beaver we must not forget the glutton as a cause for the coming into existence of that wonderful specimen of animal architecture. The glutton is the beaver's deadliest foe among animals; and the winter-residence of frozen mud is built as a fortress for the purpose of withstanding the powerful claws of this wily and well-armed savage.

With his enormous appetite the glutton combines a strange kleptomania: like certain birds and some other animals, it has a passion for hiding things. It will creep into the unoccupied tent of the trapper and carry away and bury every portable

thing that he has left, from a gun to a blanket. All things considered, the glutton is a considerable trial to the trapper who is out for furs; and there is no animal that has made a more audacious fight against man and his arts in the wilds than this lord of the wily family of weasels.

Courage and power are attributes of every member of the weasel family, and in none do we find these qualities more pronounced than in the ratel, an Indian and African representative of the tribe. Ratels are very badger-like in build, and have powerful claws, with which, in time of danger they can sink themselves into the ground with astonishing celerity. It is this fact that has given the animal the name of the "grave-digger," for it is asserted that the ratel is a robber of graves. The accusation appears to be wholly unjustified. The food of the animal consists of honey and the larvæ of bees, termites, and small mammals. The ratel is another member of the weasel family that is successfully domesticated. In captivity it makes an amusing companion, trotting about with great activity, and throwing somersaults to attract attention. But, beware of the ratel; it bites upon the least provocation, not, apparently, from malice, but, like a squirrel unhandily grasped, from fear.

THE AMUSING BUT UNTRUSTWORTHY RATEL

Specialisation reaches its highest point in the skunk, but it is a specialisation accompanied by degeneration. It is equipped with glands from which it can at will discharge a fluid as vile as asafœtida—a fluid that destroys the sight, and overcomes man or animals with nausea. Conscious of its vile powers, the skunk has abandoned all other means of defence. It has become a lethargic robber, and makes no attempt to escape when attacked, or to defend itself with its powerful teeth. The plan is quite successful, for skunks abound to such an extent in parts of America that Mr. Hudson has written as follows: "In talking to strangers from abroad, I have never thought it necessary to speak of sunstroke, jaguars, and the assassin's knife, but have never omitted to warn them of the skunk, minutely describing its habit and appearance."

The secretion that makes the animal notorious is produced from two glands near the root of the tail. In attacking, the skunk turns its back upon its enemy, raises its tail, and discharges its fluid with considerable accuracy for, if need be, a distance of from twelve or more feet. So powerful and persistent is the odour that a single drop on a man's dancing shoes has been known to stampede the whole of the company from a ballroom; while a dog that has been bespattered, after being repeatedly washed for a week, by rubbing itself against a table-leg rendered that article unusable as furniture. The skunk is one of the abominations of the animal world, but by reason of its appalling armament is permitted to continue in an abundance that is not deserved.

More engaging members of the family are well known in Britain, as the badger and the otter. The former is capable of fœtid exudation, but this is not for purposes of defence so much as a means whereby badger may track badger; and the tame badger is regarded as quite innocuous and cleanly. Like the ratel, the badger is loose-skinned, so that when seized by the hide it can readily turn, as it were within itself, and inflict an unexpected bite. And the power of the bite is such as, once experienced, is never to be forgotten.

It was because of the poor brute's courage, its power to inflict bad wounds, and to withstand them in its own person, that the badger was for long the victim of a brutal sport known as badger drawing or baiting. To draw the badger a dog of courage had to go into the animal's tub or other improvised retreat, and force it into the open. This was a feature of public-house life in rural England. This "sport" has now given place to one scarcely less wanton, in which men of leisure set their hirelings to dig out the animal, while a host of dogs wait to rend it in pieces as soon as it appears. It is a monstrous sport, of which any right-minded man must feel heartily ashamed. The badger always makes a good bid for his life, first in subterranean flight, afterwards with his teeth. For he is

the most famous of all our diggers on the heroic scale. His burrows are the biggest, best, and most perfectly made by animals in the United Kingdom. He has been longer underground, it is believed, than the fox, and has learned that scrupulous cleanliness is essential within the home. It is different with the fox, which is a noisome beast in its "earth."

It is not until man sets to work to dig out the badger that we realise the excavating powers of the animal. A typical case was mentioned recently in the "Times," in which half a dozen diggers were ordered to dig within the shades of a wood sloping down to the Severn. They started at ten in the morning, and dug till one; then rested for dinner. Afterwards they resumed, and kept at it throughout the afternoon and evening, and right away till five o'clock next morning, when at last they reached their quarry, a splendid pair of badgers, that at once fell victims to the three men who remained, and their four terriers.

NOBODY'S FRIEND: THE PERSECUTED OTTER

The badger can bury itself in from sixty to seventy seconds; and while the man with pick and shovel is tearing away at the burrow, the beast industriously excavates in the interior, extending its run, and building partitions of earth across the tunnel to prevent the ingress of dogs. Badgers and foxes occasionally share two sections of one burrow. Sometimes the badger objects, and then it is the fox that dies. The food of the badger is taken from many sources, vegetarian and carnivorous; hence the game preserver, though occasionally he may lose a nest of eggs or a few young birds, has on the whole little to fear. If for no other reason, we owe the badger thanks for his efforts in digging out and eating the larvæ of wasps.

The biggest of our wild animals, the badger ought certainly to be preserved. He has no friends beyond a few generous-spirited landowners who gave him sanctuary. It is a brutal admission that if it were possible to hunt him as easily as the fox he would be a highly treasured animal. But though he can occasionally be got to run before hounds—and a Yorkshire pack of foxhounds a little time ago killed [illegible] badgers in three seasons—the difficulty of digging him out is too serious; so, unlike the fox, the animal is not in any sense preserved. It is considered a crime for a farmer to shoot or poison a fox that raids his poultry run, because he thus deprives members of an organised hunt of the joy of themselves destroying the animal; but every man's hand is against the badger simply because to kill is one of the vicious instincts surviving in man from his early bestial days when he lived by death.

The same argument applies to the state of that beautiful animal the otter, with which our review of the weasel family terminates. The otter is a member of the tribe that has made itself master of an aquatic life, and is such an interesting and handsome creature as we ought to be proud to preserve. It lives in the main upon fish, it is true, but if we kept our riparian waters pure they would hold enough fish to satisfy the demands of man and otters as well. Besides, as the public have now no legal rights to fish in public waters, there is still less need to drive this animal from the places where it has been part proprietor since days long before the advent of the first man to Great Britain. Experience shows that otters and streams full of fish not infrequently go together. Fish will bring otters to a river; otters will not drive fish away, though they may keep their numbers somewhat in check. But it is not because he takes fish that the otter is persecuted. Many of the people who accompany a pack of otter-hounds know no more about the animal's diet and habits than the otter knows of theirs. To such the otter is something to kill, something to chase amid picturesque surroundings in the open air. There is excitement in the work of the hounds as they track the beast from place to place by the scent he has left. But

he conditions are monstrously unfair—so nany men, so many spears, so many iounds all arrayed against one small animal. n the face of such odds the quarry makes ı valiant fight. Bolted from its retreat n the bank, it takes to the water, its course racked by the mud it stirs up, and by the ›ubbles of air from its lungs. As it rises o breathe it is speared by some lusty vatcher, or seized by a dog. When atacked by the latter, the animal sinks in the ıttempt to drown its assailant. Naturally t can remain under water longer than any log, and if the latter be but staunch in his grip the otter will take his life.

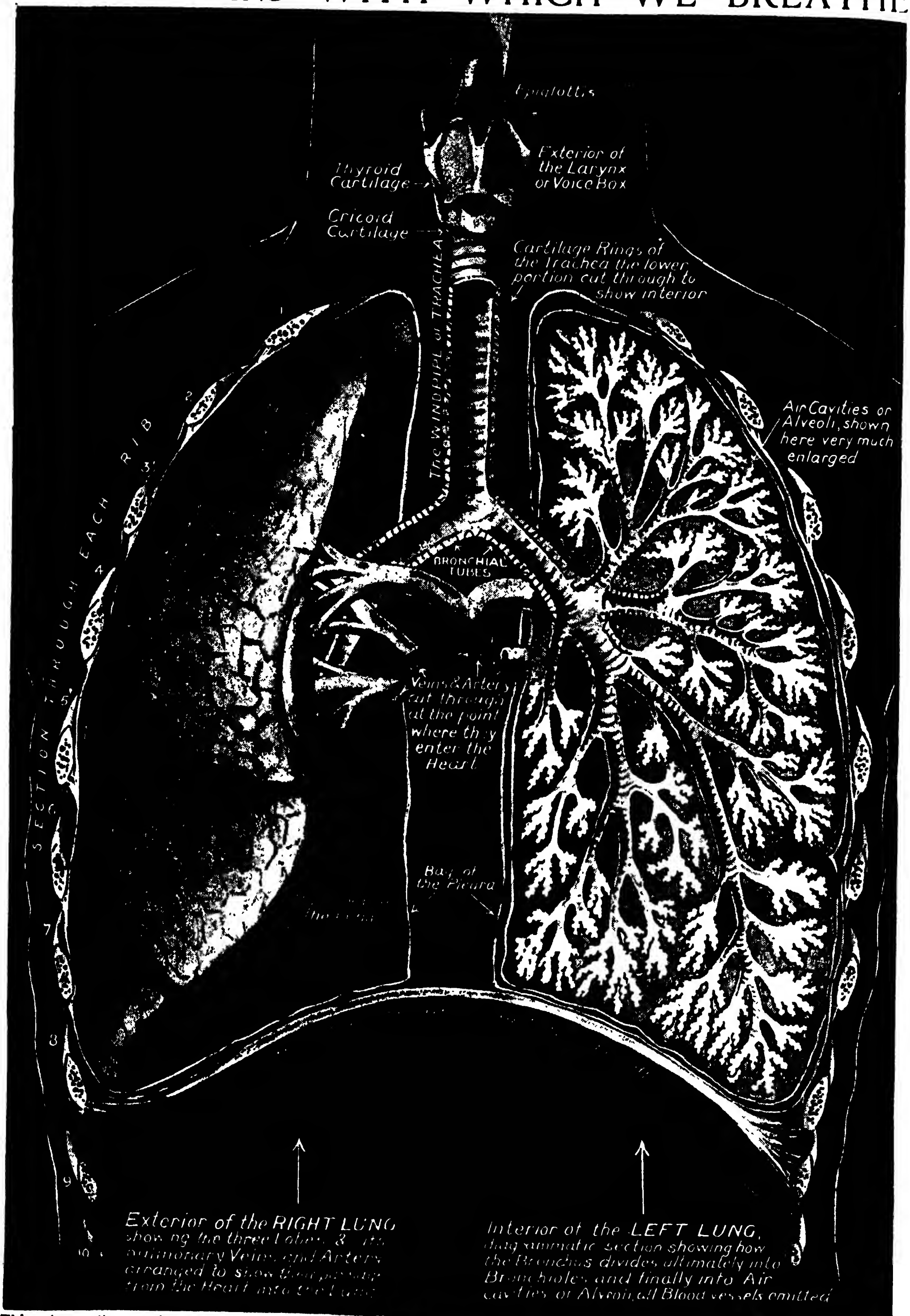
Left to itself, the otter rests for the greater ›art of the day in its holt near the stream, ınd comes out at night to feed. Under ›rdinary circumstances, careful watchers ıssert, the fishes that the otter takes are mall or diseased. t has only the ight in which to atch fish for itself ınd for its young, ınd has no time o waste in useless hase of big, fleet ish. Instead, herefore, of depleting a stream, t keeps the water ree of disease, and s, so the otter's riends argue, an ıctual benefit to a ishery. When ıeavy frost locks ıp the water, the ›tter may be lriven to turn its ıttention to life on land, and at such times nay attack poultry and even game. But ıow often does such a season occur in England? Surely this gay and handsome vater-weasel has as much right to the little ood it is compelled thus to take once in a ew years as the fox has throughout the whole of the year.

No animal is more readily educated than ı young otter. It is naturally a playful ›east, and its slides down the soft soil of a iver bank or in the snow are well-known eatures of its habitat. In captivity it hows all its natural playfulness and affecion towards its master. It is readily aught to follow like a dog; it will enter he water and leave at the word of command. When it is to be instructed in the art of ishing for another, it is first broken to a diet of milk and bread and other things, so that it shall not regard fish as the be-all of existence. Then it is taught to retrieve things on land, and afterwards made to fetch and carry a dummy fish, which is thrown into the water. Then comes the catching of a real fish cast into a stream. If the otter eats the fish, it is rebuked; if it brings it to its master, it is rewarded. In this way it soon learns its lesson, and comes to the catching and bringing to foot of fish snatched from the stream.

A VANISHING SPECIES: THE COVETED SEA-OTTER

Otters take readily to life on the seashore, but these must not be confounded with the true sea-otter, which, as our illustration shows, is quite another animal, and more seal-like than its congener. The sea-otter is referred to a genus apart from the other otters, as is bound to be the case when we consider the structural differences between the two animals. The long hind legs of the sea-otter are a kind of glorified example of the seal's flippers, and the fore limbs are very short. It is to be feared that there will not be much opportunity in the future for us to become familiar with this animal, for so highly esteemed is its fur that it has been almost exterminated in spite of the extraordinary acuteness of its sight and hearing. The bludgeon, the rifle, and the net have been too much for it. It was driven from its breeding-places on shore to banks and masses of floating weed, but the hunter still followed; and to-day so scarce has the animal become that a sea-otter's skin fetches from £200 to £300. A sort of attempt has been made to domesticate this animal, but such is its mortal dread of man that the young ones captured have died, as much from terror as from the want of the food that fright prevents them from taking, an ending sadly in keeping with man's relations with all the wild creatures we have grouped in this chapter as the weasel family. He could gain their confidence still if he had retained that keen sympathy with free life which must have been one of his primitive instincts.

THE ORGANS WITH WHICH WE BREATHE



This picture-diagram shows the two lungs as they are placed in the chest, the encircling part of the ribs being omitted for clearness. The right lung is shown complete, with its three lobes, and the left lung in section. An inspiration has just been taken, so that the chest is distended and the diaphragm flattened somewhat, exposing the large extent of the back of the lung. The front part of the lung is slightly pulled aside in the drawing to allow us to see more clearly the entrance of the artery and the exit of the veins which carry the blood to and from the lungs.

THE RESPIRATORY SYSTEM

How and Why We Breathe with Unconscious Regularity, and with What Results

INCONVENIENCES LEFT BY EVOLUTION

The body of man is an animal; the characteristic organ of the body, looked at simply as an animal, is its brain; and this brain is the throne of Man. We proceed, then, to study the machinery and substructure of this brain, clearly realising that the various systems which we have to study exist for the brain, and are only worthy of note on that account.

We come, therefore, to the system which exists in order to ventilate the brain and those other parts of the body that, in one way or another, serve the brain. In this fashion we shall gradually climb, up the animal, to man himself, who is our real business in this section.

As for the respiratory system, we may remind ourselves that all living things breathe, and that the microbe and the amœba and the alga must have a respiratory system, no less than man has—though visible machinery may be absent; and, further, that the structures which we describe in man's body are to be found, in all essentials, no less well developed in a multitude of other species. They are in no sense characteristic of man, but they mightily concern him, for his brain must be ventilated, and this is the indispensable function which they serve.

Primitive organisms breathe by their whole surface—that is to say, the interchange of gases, which is the essence of breathing, occurs wherever the body and its gaseous environment meet. Somewhat higher organisms invent special machinery, but can breathe more or less through the skin. But man, like his nearer allies in the animal world, can take in air only by a special channel. This intake of air we call breathing, or respiration. But it is obviously only the mechanical preliminary to the real breathing, or "tissue-respiration," which occurs in the living cells of the body everywhere, and for which what we commonly call breathing exists.

The real parallel to the breathing of the amœba is that of the white cell in the blood, which helps itself to oxygen therefrom, just as the amœba helps itself to oxygen from the external atmosphere. In effect, what we call breathing, together with the circulation of the blood, exists in order to provide every living cell of the body, in the upshot, with an immediate environment of oxygen, such as the amœba has; and this arrangement is so completely carried out that even the cells of the skin, which are next the external atmosphere, breathe not the oxygen therein, but the oxygen that is brought to them by the blood from the lungs.

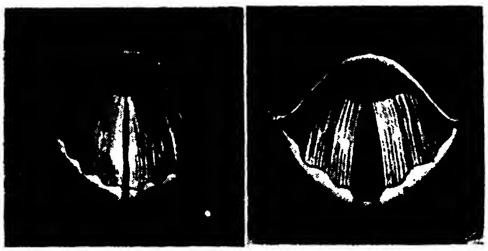
The air, or wind, is conveyed into the interior of the body by the windpipe, or trachea, of which anyone may feel the upper portion just below the larynx, or voice-box. In order that the man shall live, it is absolutely essential that a sufficiency of air shall pass down his windpipe, and a sufficiency of different air return. How the air gains admission to the pipe is a secondary matter—of high importance, but secondary. In certain circumstances a hole may be made in the windpipe, or trachea, and may be kept open by a tube, and may suffice for an indefinite period—even extending to months or years.

This operation of tracheotomy was incessantly performed, and saved life, before the introduction of the diphtheria antitoxin, and is still required at times in various cases. If anything becomes impacted in the larynx, an emergency opening may be made by a penknife or what not between the large projecting cartilage of the larynx and the ring of cartilage just beneath it. This "laryngotomy" may thus permit the continuance of life. Scarcely more normal

than the entry of air to the windpipe by a hole in itself or by a hole in the larynx is its entry through the mouth, as in "mouth-breathers." The mouth may, however, be admitted for this purpose in forced respiration, as in violent exercise. But the bodily apertures constructed for respiration are the nostrils, and the nostrils alone.

They are the beginning of the respiratory system, the end of which may be named in the air-chambers of the lungs, or, more logically, in the actual cells of the body everywhere in which the act of tissue-respiration is consummated.

The air entering the nose is warmed, moistened, and largely filtered, both of dust and microbes. It passes freely through the throat, from the back of the nose to the opening of the larynx, cutting, however, across the path of food or drink to the gullet. This is a source of some danger to the body, and kills a certain small proportion of mankind. But many arrangements have nevertheless been made to minimise this risk, which is due to the evolutionary origin of the respiratory system of man in the swim-bladder, or air-bladder, of the fish.



VOCAL CORDS, CLOSED IN SINGING AND OPEN IN BREATHING

Before we roundly condemn this inconvenience and mechanical stupidity of the body, we should consider the real significance of the step which those pioneer fishes of long ago took when they first made possible the coming of air-breathing vertebrates. The air-bladder of the fish, containing air in varying quantity for convenience of adjustment between the specific gravity of the body of the fish and that of the water at various levels, furnished the possibility of an entirely new idea, the intake of air from air in mass, instead of from the exiguous quantities which can be dissolved in water. Hence, when this idea was realised, and life swam ashore, all the higher possibilities of beast, bird, and man were potentially realised.

In all but one in a thousand cases of choking, however, the trouble is not mechanical but spasmodic. Some drops of fluid, probably, have entered the larynx and set up irritation. The vocal cords well know that no food or drink should enter the larynx and reach the lungs They tightly close the aperture to make further entry impossible. This involves temporary suffocation, with its inimitably horrible sensations; but it is absolutely certain that, just so soon as the carbonic acid in the blood mounts up a little, it will paralyse the spasm of the vocal cords, which will relax, and in a fraction of an instant he who could not breathe at all will be inhaling a full flood of air. Those who know and understand the sequence of events, in this fashion, suffer much less when they choke, as they are freed from the sense of impending death, knowing that the cords will relax in a few seconds.

The presence of the larynx with its cords, and the very narrow gap between them at the top of the windpipe, is a modern adaptation for speech. It has nothing to do with respiration, save only that respiration involves the movement of air, and sounds are made in air. This is another instance of the inventiveness of life, but need not be discussed further until we come to consider human speech—the great achievement of the human brain—and its vocal instrument, the larynx.

The windpipe is unlike nearly all the other tubes of the body in that it is always open. We think of the gullet, and many other tubes, as permanently open. But, in point of fact, their walls are in constant apposition except when something is passing along them. It must be remembered that the whole of the body is subjected to the pressure of the atmosphere, and there can be no such thing as a merely vacant tube in it. But the trachea requires to be constantly open, and for this purpose its walls are stiffened by the rings of cartilage, the first few of which we can readily feel in the neck just below the larynx. The tube is lined throughout with cells of a peculiar type, equipped with what are called cilia—or "eyelashes," as the word means. These ciliated cells have the function of constantly lashing upwards any fluid that may be in the larynx.

The ciliary motion is invariably upwards—towards the mouth and nostrils, just as the ciliary motion of the similar cells in the nose is always downwards, again towards the nostrils. Not only fluid, but also a great quantity of solid matter, dust, and microbes, is caught in the sticky secretion of the interior of the trachea, and then whipped

upwards by the cilia. We note about ciliary motion, here and elsewhere, that it is totally independent of nervous control, unlike the motion of muscle cells, striped or unstriped. The same is, of course, true of the motion of the leucocytes, or white cells, of the blood. Both white cells and ciliated cells move independently of any central orders or direction, but none the less in orderly fashion and wholly for the service of the body. We note, also, that ciliated cells and white blood-cells both closely resemble humble forms of animal life such as we find in ponds.

In tracheitis, or inflammation of the trachea, such as always accompanies bronchitis, or inflammation of the bronchi—which are the further divisions of the trachea—the ciliary cells are all shed, for the time, leading to stagnation of the secretions, and the irritation which shows itself in the need to cough.

The trachea divides into two, forming the right and left bronchus, one for each lung. This subdivision continues, the vessels becoming smaller and smaller, until they are called bronchioles. In essentials, the structure of this tree-like arrangement is the same throughout, but the proportion of cartilage gradually diminishes, and unstriped muscular tissue becomes conspicuous in the walls of the smallest tubes, which have no cartilage at all. We here see a parallel to the case of the blood-vessels, of which the largest have a high proportion of fibrous "stiffening," so to say, with very little muscular tissue; while the arterioles, like the bronchioles, consist of little more than muscular tissue. In the case of the arterioles, their muscularity has an evident function; but there does not seem to be any evident reason why the quantity of air going to any particular part of the lung should be controlled, and, indeed, all we know of the muscular tissue of the bronchioles is little to their advantage. This tissue is, of course, under the control of nerves, and, being unstriped, is involuntary. Only too often it is thrown into contraction unnecessarily, producing the "nervous asthma" which, in time, gravely injures the value of the lungs by interfering with the act of expiration, and leading to stretching of the elastic tissue that abounds in the lungs, and is so extremely necessary for their healthy functioning.

All that we have described so far is, of course, no more than a system of ducts. The essential lung-tissue, to and from which they convey the air inspired and expired, is packed all round them—a spongy, highly elastic tissue, always with air in it, and very richly supplied with blood-vessels. The lungs of an infant which has never breathed will sink in water, but if only one breath has ever entered lung-tissue it will always float, a quantity of air remaining in it even after the utmost possible effort at expiration.

THE AIR AND FOOD PASSAGES

Showing a lump of food lodged at the top of the windpipe, causing choking.

We are to understand, then, that the ultimate divisions of the windpipe lead to a vast multitude of air-chambers, each somewhat expanded around the end of the tube which it caps, rather after the fashion of a child's collapsible balloon. The lungs are simply an enormous number of such expansible sacs, which can be filled and emptied alternately; and the air as it leaves may make sounds, as in the "dying pig," or in the human larynx. There is a difference in the manner of filling, for the air is forced into the child's toy, while it is sucked into the lungs—the one requires a force-pump, and the other a suction-pump; but both alike are normally emptied chiefly by the inherent elasticity of the material of which they are composed.

Imagine now a very close and very fine network of tiny blood-vessels spread over the child's balloon, with blood always running through them, and the parallel is complete. Certain gaseous substances will be liable to pass through the membrane, in both directions, altering the composition of the blood and of the air in the sac respectively; and that is exactly what happens when we breathe. If we can imagine a huge bag of this kind, with an area of some two thousand square feet, it would represent, essentially, the structure and arrangement of the two lungs. They are simply devices for rapidly and continually exposing

to the air for purification as large a quantity as possible of blood.

One structural fact of the highest importance remains to be inquired into. What, precisely, is the kind of partition—or communication, for it is both—that stands between the air and the blood in the lungs? It is very thin indeed. There is first, of course, the wall of the capillary blood-vessel, but that consists of no more than a single layer of flat, thin cells. The lung itself is lined with rather large cells, in a single layer, perfectly flat and very thin. The plump, ciliated cells are not prolonged into the ultimate chambers of the lung. Thus the exchange of gases may take place through what is practically no more than a double layer of thin, flat cells. And we naturally ask how the exchange occurs.

Altered Opinion as to the Method of Purification of Blood in the Lungs

It was long taught, in accordance with the prevailing mechanical philosophy of the time, that the exchange of gases in the lung was entirely determined by those laws of gaseous interchange which apply elsewhere. This statement, and all statements like it, depend upon a confusion of thought. The laws of physics and chemistry are truly universal. Gravitation, to take one instance, acts within the living body, and upon it, and by it, as everywhere else. The laws of gaseous diffusion, and so forth, similarly apply in the body, and it is a legitimate and valuable triumph for science when it can demonstrate the working of these physical laws in the living body. But this is not to say that life does nothing. It is only to say of life what Bacon long ago declared of the highest form of life—which is man—that Nature can only be commanded by obeying her. The laws of Nature are thus obeyed by life, in order that they may be commanded.

The Active Part Played by the Cells Beyond the Passive Process of Gaseous Diffusion

In the extremely important instance now under discussion we have reason to believe that the gaseous interchange in the lung cannot be wholly attributed to the laws of gaseous diffusion, even though those laws are, of course, at work in the lung as everywhere else. A vital part is played by the vital activity of the flat cells which line the lung—cells which, though flat, for an evident reason, are yet unlike such flat cells as those of the skin, for the lung cells have not lost their nuclei, a fact which in itself suggests that their function may be much more than merely mechanical.

Examination of the difference between inspired and expired air shows us what happens in the lung, and corresponding changes are to be found in the gaseous contents of the blood in the pulmonary veins, returning to the left side of the heart, as compared with that in the pulmonary arteries, running from the right side of the heart to the lungs.

We have said gaseous contents, but it is to be noted that water evaporates, so to say, from the blood in the lungs, and is added to the expired air. We, in fact, perspire through the lungs. This evaporation is remarkably rapid, and we perhaps scarcely realise that the water which condenses again from our breath in cold air in such quantities was actually in our blood a few seconds before. It is very doubtful whether some vital activity on the part of the lung cells is not required to explain this abstraction of water from the blood.

This, observe, is not to say that the laws of aqueous evaporation are abrogated, but merely that we cannot explain the facts on the assumption that the lung cells are inert in the process. The loss of water by the lungs—amounting on the average to about nine ounces daily—is not of the first importance, as the body can also dispose of water, and so make room for more, by means of the skin and the kidneys.

The Double Purpose of Breathing—Absorption of Oxygen and Excretion of Poison

Expired air is also warmer than inspired air, assuming that the external temperature is lower than that of the body. Thus the blood loses heat, as well as water, to the expired air, and is very definitely cooled in consequence. The blood going to the body generally, after its return to the heart from the lungs, is thus relatively cool. We shall shortly see where and why it is warmed again, but meanwhile we note that *no combustion occurs in the process of breathing*, as is sufficiently proved by the fact that the blood which leaves the lungs is cooler than when it entered them.

Yet if we closely examine the gaseous composition of expired air we may well suppose that combustion has occurred in the lungs, as used to be supposed. For we find that expired air contains less oxygen and more carbonic acid gas than inspired air, just as if it had been supporting combustion in the lungs. We have seen, however, that the temperature-change of the blood negatives that view, and we find further that the carbonic acid gas has not been made in the lungs at all, but has merely been discharged

there, as the blood passed through them. Much of the water, and nearly all of the carbonic acid gas in expired air, has indeed been made by the combustion, or union with oxygen, of hydrogen and carbon respectively, in the body, but not in the lungs.

This will be understood soon; meanwhile we observe that the removal of carbonic acid gas from the body in expired air is the most characteristic part of the whole business of breathing. The incessant combustion of carbon, with production of carbonic acid gas, is necessary for all forms of life, and it is further necessary that all living things shall get rid of the carbonic acid gas, which is a poison to them. We rightly say that the carbonic acid gas is a food of plants, but the plants decompose it, and take the carbon only. If they absorbed the gas as it is, it would poison them, and a plant requires to be rid of the carbonic acid gas produced by its breathing, just as we do.

DIAGRAM SHOWING HOW THE DIAPHRAM HELPS TO FILL AND EMPTY THE LUNGS

We realise, then, once and for all, that the rhythm of breathing is fundamentally different from, say, the rhythm of swallowing. We are not simply inhaling oxygen in successive quantities. Breathing is essentially a double process, partly absorption, partly excretion. The act of inspiration provides the body with what it must have in order to live; the act of expiration rids it of what it must lose in order to live. This necessary removal of carbonic acid from the blood cannot occur in any degree except through the lungs alone, and the ever-desperate urgency of breathing is above all due to the absolute necessity of getting rid of the deadly poison which the body is always producing within it.

If we die by asphyxia, the cause of death is not oxygen-starvation, but carbonic acid poisoning. It is, indeed, in the modern phrase, auto-intoxication or self-poisoning, which is the incessant risk of all forms of life. When a man is compelled to breathe again and again the same air in a confined chamber, he can still live when the proportion of oxygen in his atmosphere is only six per cent., provided that the carbonic acid which he is producing be continuously removed. But if this be not done, the difficulty of breathing becomes extreme when the proportion of carbonic acid reaches five or six per cent., though there may still be as much as sixteen per cent of oxygen in the air. Not starvation, then, but poisoning, is the conclusion of this experiment, and we shall some day learn that it applies equally to the problems of ventilation, and of, say, the want of proper nutrition in the children of the poor.

The pumping arrangement next concerns us. The heart, which pumps fluid from the body, is a force-pump; the pumping of air is done by suction. The lungs are contained in an extensible and elastic box, called the chest. Each lung has wrapped round it a closed, empty, collapsed bag, called the pleura, of which one side lines the chest-wall, while the other covers the outside of the lung, these two walls being in continuous contact at all times, save when there is pleurisy, and fluid is produced and poured out between them. When we inspire, we enlarge the capacity of the chest, and as "Nature abhors a vacuum," which would otherwise be formed in the pleura, by raising its outer from its inner wall, the lung rises with the wall, and air rushes in to enable it to do so. In other words, air is sucked into the lung by means of the atmospheric pressure. Each lung has its own pleura, and is independent in this respect. If the chest-wall be pierced, and air is admitted into the pleura, the atmospheric pressure now becomes equal on the inside and the outside of the lung. In virtue of its natural elasticity it instantly collapses. If this should happen to both pleuræ, there can be no alternative to death following at once.

The enlargement of the capacity of the chest, whereby air is sucked into the lungs, is effected by muscles, and is one of the most important parts of the internal work of the body. The skeleton of the chest is so arranged that the ribs, when raised, increase its capacity. At the same time, a thin sheet of muscle, the diaphragm or midriff, which forms the floor of the chest, and which, when at rest, is convex upwards, becomes flattened, thus increasing the depth of the chest. Like the other movements of the body, whether automatic or willed, this is a concerted movement, employing a

combination of muscles in a co-ordinated way. We thus recognise a group, "the muscles of inspiration," just as we recognised "the muscles of expression" in and near the face.

The Intimate Relation Between Wise Dress for the Body and Healthy Breathing

The principal muscle of inspiration is the diaphragm, and the next most important are the muscles which lie between the ribs or costæ, and are therefore called the intercostal muscles. In forced respiration a number of other muscles may be called into play, forming the "accessory muscles of inspiration," and their action may be witnessed in various forms of disease, in the breathing of a woman who has as far as possible thrown her diaphragm out of action by a tight corset, or in the breathing of a badly trained singer. The foundation of all good and natural breathing, in both sexes and at all ages, notwithstanding former statements to the contrary, is the use of the diaphragm; and whatever habits of clothing, or of drill, or posture, prejudice or hamper diaphragmatic breathing, strike directly at one of the roots of normal living, which we call health.

There are no muscles of ordinary expiration. When the contraction of the muscles of inspiration ceases, the chest subsides, partly by its weight, but mainly by the elastic recoil of the muscles of inspiration, the elastic recoil of the slightly twisted ribs, and, above all, the elastic recoil of the lungs themselves. One of the most subtle and characteristic changes produced in the body as it passes its prime is loss of elasticity. We observe this in, for instance, the lens of the elderly eye, which consequently becomes long-sighted. The same is true of the chest; and the general rule is that our chest measurement slowly but surely increases, as the elastic recoil of expiration becomes less perfect.

How Our Unconscious Breathing Responds to Suggestion from Outside, as in Yawning

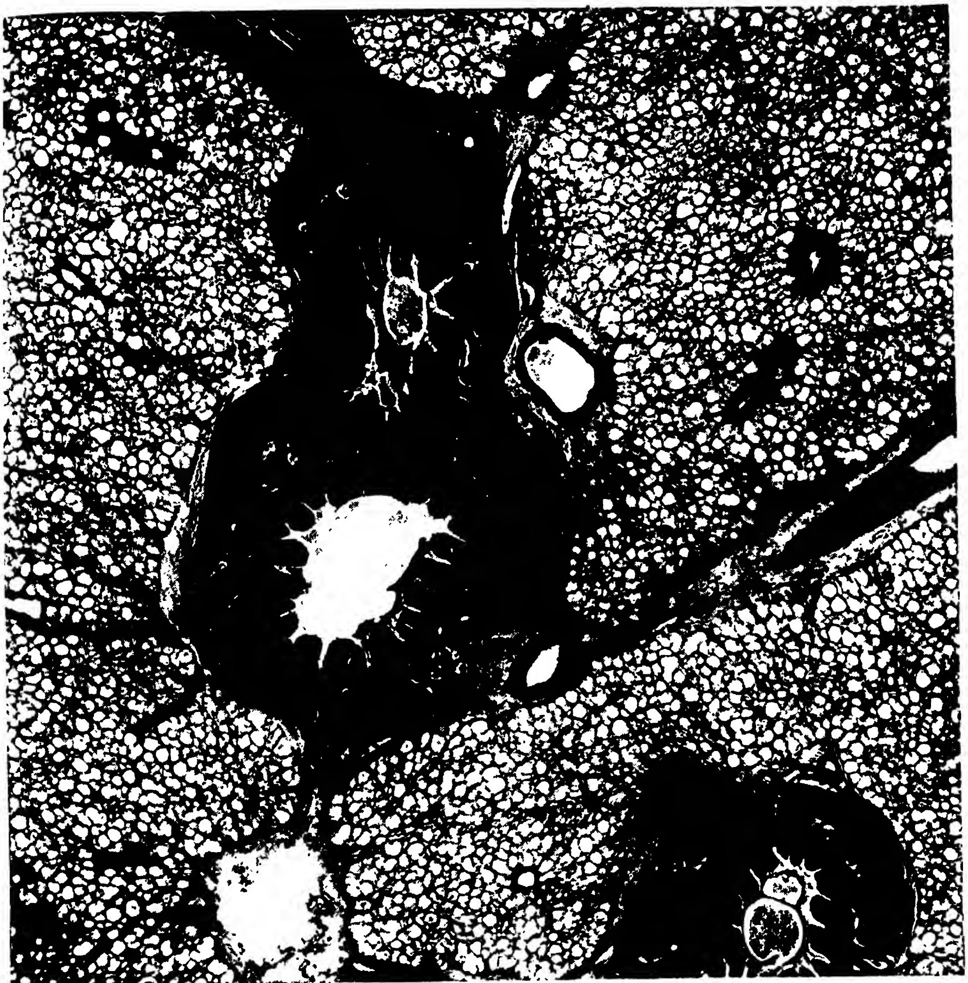
In forced expiration various muscles come into play, muscles far more numerous and varied than anyone could imagine who had not witnessed an asthmatic patient, sitting up in bed, and forcing the air out of his lungs through his contracted bronchioles, which should be freely open. These muscles, or some of them, come into play in all the other forms of forced expiration, such as speaking and singing, when the breath is forced against resistance in the larynx; coughing, when it is forced against resistance anywhere in the air-passages; and sneezing, when it is forced against resistance in the inner parts of the nose.

Yawning, on the other hand, is essentially a forced inspiration, due to a suddenly increased activity of the nervous centre which we are about to describe. Sighing is closely allied to yawning, and both are efforts on the part of the respiratory centre to compensate for the deficient aëration of the blood which has been induced by sadness or boredom. The remarkable fact has long been noted that nothing is so infectious as yawning, and nothing more communicative of depression than sighing. Human suggestibility, in a word, is highest to symptoms which concern the most continuous and urgent of human needs, which is to breathe. We cannot have it suggested to us, by another, that breathing is much required, without the oldest centre in our own nervous system responding, and we yawn or sigh also, lest we too should die for lack of breath.

The Quick Adaptation of Our Respiratory System to the Temporary Needs of the Body

This respiratory centre, or *punctum vitale*—the "vital point" of the older physiologists—is a minute point of nervous matter in the oldest and lowest part of the brain, called the bulb. We shall hear a good deal more about this bulb later, for it contains all the chief centres necessary for the nutritive life of man. The respiratory centre ceaselessly controls the whole process of respiration, from the initial breath of birth until the end, maintaining a steady and fitting rhythm. From it proceed the nerves which govern, directly or indirectly, the muscles of inspiration. To it there run nerves from various parts of the body, but chiefly, of course, from the lungs and pleuræ, the larynx and nose, which are able to induce the respiratory centre to order a cough, a sneeze, a yawn, or any other necessary adaptation to the circumstances of the moment.

But the respiratory centre is, above all, sensitive to the blood which flows through it. The nerve-cells are closely aware of the temperature of the blood, and thus induce faster respirations in fever. More closely than this, however, are they aware of the exact proportion of carbonic acid in the blood, instantly making any effort, at any cost to the muscles, or to any other part or interest of the body, whenever the proportion of this deadly poison, which the body is ever producing, tends to rise above the tiny quantity permissible. "Eternal vigilance is the price of liberty," and the



HIGHLY MAGNIFIED TRANSVERSE SECTION THROUGH A LUNG, SHOWING BRONCHI

nerve-cells of the "vital point" know that it is also the price of life.

Lastly, we note that all this is merely preliminary to the inner, or tissue, respiration, for which the blood carries oxygen to the tissues, and in consequence of which it carries carbonic acid away from them. There it is that the blood acquires the heat which it partly loses in the lungs, for there it is, in the tissues, and not in the lungs, that the real combustion of the body occurs. It occurs in all parts, but most notably in the muscles and the glands. We may figure it as a simple process, and its principles and essential conditions are simple, but it is really very complicated. As we have already seen, this combustion occurs *in water*, and not very hot water at that; and though the business of breathing exists in order to expose the body to an endless and continuous draught, bringing oxygen, and removing carbonic acid and water, the actual details of the combustion are far more complicated than our present knowledge can follow.

It is enough, for the present, to note that an isolated muscle, no longer fed with blood, can contract for some time in an atmosphere of pure nitrogen, so that it is getting oxygen from nowhere, and can yet give off carbonic acid, which is a compound of carbon and oxygen.

This means, of course, as we must never forget, that the breathing of protoplasm is vital and internal, that its oxidation is *intra-molecular*. It is for this intra-molecular oxidation of the living protoplasm of our bodies and for the removal of its products that we breathe, since the body of man is a living animal. But we must hurry on, for though it mightily concerns him, this is not yet Man.

DREAMS OF VICTORY BY FRENCH SOLDIERS ON THE NIGHT BEFORE A GREAT BATTLE

THIS FAMOUS PICTURE, ENTITLED "LA RÊVE," BY THE FRENCH ARTIST DETAILLE, IS NOW HANGING IN THE LUXEMBOURG GALLERY PARIS

ELUSIVE PROBLEMS OF SLEEP

How the Dangers of Insomnia May be Incurred and How they May be Overcome

THE EVIL EFFECTS OF THE DRUG HABIT

Unless we have already forgotten our first principles we cannot promise sound sleep for all, by whatever device. We all vary, and some are born to sleep well, and others to sleep badly. Yet there remains a wide field of folly and wisdom in this matter, which each may cultivate as he will, with appropriate results.

The science of sleep is more in need of study every year. Doctors have no doubt that insomnia is increasing. It would be strange indeed if the suicide rate steadily rose, as it does, without a general increase in insomnia, which is the almost invariable precursor of suicide.

Insomnia is bound to be a disease of an age which uses the upper areas of the brain, those most concerned in sleep, more than they were ever used before; an age which eats liberally, not least at night; is huddled together in cities, taking little natural exercise; has lately begun to fill those cities with all manner of unprecedented noises, ranging from the underground railway, through the indescribable streets, up to the aeroplane overhead; an age, lastly, which drugs itself with potent and novel compounds, all directly designed to act upon the nervous system, as it was never before acted on in the history of the world.

The consequences are traceable in general and in detail. Civilisation is built upon control, and any high civilisation is built upon self-control. In this matter we are getting rather out of hand in recent times. It need only be remembered that the man who has not slept is irritable, hasty, vacillating, not master of himself, for us to realise that the quality of sleep obtained by its units may be momentous for the destiny of a civilisation.

As for detailed instances of the evil against which this chapter is directed, their name is legion. Almost everyone who can afford it has to have a rest-cure, or its equivalent, at occasional intervals nowadays. Hundreds and thousands of fine and useful workers are ruined for life by insomnia, lost to themselves and the world, usually with the devilish help of some drug or other.

Charles Darwin and Herbert Spencer, whose thoughts and in whose terms all men now think who think to any purpose, were lifelong sufferers in this respect. Too strong and great to have recourse to drugging, or to give up working, they went on as best they could, but all men are the losers for their disability.

Spencer's book on psychology made a new epoch in that science, but he wrote it in defiance of the laws of health, and for forty years thereafter he paid the price, never having one really good night again, and often being compelled to cut his working hours down to two or three, while four was his maximum. These are great and notable cases, but they are far from being extreme.

Yet here is something which, like everything else, has its causes, and those causes are, on the whole, understood. Sleep and insomnia are very complicated phenomena, and the causes of insomnia are accordingly numerous. Further, our problem lies at, so to say, the very junction of mind and body; and thus the cause of insomnia may equally well be an undigested supper, a noble strain of music, or a secret sorrow, and its relief may be found in a drug or a bath or the sound of a dear voice.

Nevertheless, sleep and lack of sleep can be controlled, in ourselves and in others. No case is hopeless. Asylum physicians master cases so bad that ordinary people have no idea of them. There are many persons in the country at this moment who will commit suicide within a week, but who

would certainly be saved if they had the wisdom and opportunity to consult a competent doctor of the mind and to follow his directions implicitly.

More than this—though here indeed we anticipate a future which will not be yet awhile—the modern students of the deeps of our minds report that there is such a thing as self-suggestion or self-hypnotism. Their teaching, as to the truth of which there is now no doubt, amounts to this. Sleep is closely allied in its nature to the hypnotic state or hypnosis (hypnos being Greek for sleep). The hypnotist can induce either hypnosis or ordinary sleep, at his pleasure, in suggestible persons.

The power of the hypnotist depends in reality upon the patient himself, as the systematic study of hypnotism in another section of this work will show. All suggestion is really self-suggestion ; the hypnotist merely makes this possible by providing us with the faith and confidence—or credulity, but the name does not matter—which are essential to all suggestion. Why, then, should we not suggest to ourselves ? Call it " will power," most abused of phrases, if you prefer, but the fact remains. We can will ourselves to sleep.

Will Man, Who Measures the Stars, Ever Master His Own Mind?

Those who have been hypnotised and given confidence on the subject by means of suggestions conveyed during hypnosis have only to tell themselves to sleep, thereafter, for whatever period they care to name, and sleep they will, and waken punctually too. As for people of stronger fibre, they can command themselves. We know that Napoleon, for instance, could sleep whenever he pleased, no matter how critical and exciting the circumstances. In that respect, at any rate, he was conqueror of himself, and greater, therefore, than the conqueror of cities. Many other instances are on record. No doubt what is possible for some may be learnt, in degree at least, by all, for we are all suggestible, and even the strong man who believes in no one else may believe in himself. There is here foreshadowed a new stage in human development and progress, asserted to-day only by a few one-sided " cranks," who spoil their case by denying obvious realities, and yet who have a real case to state. We, who already measure the stars and harness the lightning, shall some day master our own minds.

The facts revealed and analysed by modern hypnotism consort exactly with common experience. The factor of suggestion is cardinal in sleep. It plays a part in all our lives, and how can it fail to be conspicuous here ? For the good sleeper and the hard worker the question does not arise, but for the rest of us it is all-important. We expect to sleep, and usually we do. We have confidence or " self-confidence," which is none other, obviously, than a form of " self-suggestion " or " auto-suggestion." Or the room is strange, and we have persuaded ourselves that we can never sleep the first night in a strange bed, and so we do not. Now that is the opposite of self-confidence, and the modern psychologists have their own name for that also. They rightly call it " contra-suggestion "—that is, contrary or against suggestion.

How People do not Sleep Because They Think They Cannot Sleep

This contra-suggestion in the matter of sleep is one of the curses of the modern world, and is well entitled to be placed in the forefront of the present argument. People who suffer from insomnia may remove every other factor of disturbance. They modify their diet, and get the digestion right ; they take exercise and massage, avoid excitement and stimulant beverages like coffee, and sedulously devote the whole of their day, the whole of their thought and intention, to the problem of getting to sleep at night, and they fail. The truth is that everything they have done during the day in order to sleep has fed contra-suggestion. The incessantly reiterated idea, half in the consciousness, and half in the deeps below, has ever been : " I fear I sha'n't sleep, but perhaps this will save me." And then the price is paid, and very heart-breaking it often is.

The Compelling Charm of the Confidence Which Gives Us Faith

If, however, the spell be reversed, all goes well. If the patient believes, if he or she goes to some establishment in company with a friend who positively asserts that the treatment cannot fail, it does not fail. Nay, more, the treatment is a trifle if the faith be instilled. The local doctor may have done his level best and failed. A celebrated consultant is called in, with his prestige, his confident and illustrious manner, his all-conquering voice. He says that all is well, that the treatment is perfectly correct, that the patient will almost immediately respond, and the patient does ; or he may even say that new and compelling measures are required, and write a prescription for a subcutaneous injection, but that is only a

little salt and water in Latin guise; and the injection may work like a charm, which, indeed, it is. Such experiences as this are often very hard on the local doctor, who may have done all that science can do for his patient—except apply powerful suggestions of healing, which the mere fact that he is the local doctor excludes.

The practical moral of all this, which is of such obvious scientific interest, is that we must be sensible and hopeful about our sleep, when there is any reason to think about it at all. We really can sleep if we will only believe it.

The Smallness of the Part Played by Pain in Cases of Sleeplessness

Pain is another matter. Here we are not dealing at all with the problem of pain, for that is a thing apart, and requires the appropriate treatment according to its cause. If the pain cannot be removed or relieved by any other means, then only powerful hypnotics, like morphine or hyoscine, will produce sleep, and such cases are only for the responsible doctor, directing them from hour to hour. But the general problem of bad sleeping lies apart altogether from pain, and that is what we are dealing with here.

It may be added, however, that the familiar pain called headache does not count in this connection. There is headache due to local disease within the skull, and that interferes with sleep; but according to Sir William Gowers, the greatest living authority on the subject, it is only headache due to such causes that prevents sleep, and his dictum excludes every headache but one in millions. We are therefore to regard the problem of curing insomnia, in all cases where there is no pain, and in practically all cases where the pain is only headache, as one within our own competence to solve, if we will be sensible and brave.

Rest in Bed, and not Drugs, the Natural Cure for Headache

The dictum of Gowers, quoted above, is of interest to the doctor, because it may help him to diagnose some rare malady of the brain. But it is of the greatest practical importance to the public at large, if only people knew it. It means that no one has any right to take, or to advise, or to administer any kind of drug for the relief of ordinary headache in order to obtain sleep.

After all, it is the experience of everybody that we can take a headache to bed and sleep. The mere going to bed is treatment for the headache—rational and scientific treatment, because it removes the cause, as a rule. Going to bed means rest for the circulation, to some extent, and lessening of the bumping within the skull. It means complete rest of the very probably overstrained eyes; it means a more even distribution of the blood within the body, and it discharges the brain from the duties of balancing and so forth which it has performed all day. The simple consequence is that the headache does not keep us awake, for it is being well and accurately treated by going to bed, and soon disappears.

We must deal later with the problems created by modern self-drugging, whether with hypnotics or anodynes or anything else. But here we definitely condemn the use of any anodyne drug for the relief of headache on the ground that one wants to sleep. The drugs most commonly abused for this purpose are acetanilid or antifebrin, phenazone or antipyrin, exalgin, antikamnia, and their allies—coal-tar products made in Germany with great chemical skill, but entirely unsuited for administration to human beings except under expert supervision, if at all.

The Untimely Activity of the Mind Caused by Emotion or Worry

We have seen that the mental machine is sometimes apt to go on running when we want it to stop, just as it neglects to run freely for some time after we want it to. These are illustrations of the general law of inertia, and need not surprise us. But emotion and excitement are far more important in this connection than pure work as such. Pleasurable emotion often keeps people awake—notably young people, who take their pleasures keenly. This warning especially applies to nervous and sensitive and clever children.

Wise parents and guardians give such children plenty of time to settle down before bedtime, and keep their parties and excitements to sensible early hours, as our parents did with most of us, but as few parents remember and observe nowadays. Even older people may lose their sleep through pleasurable excitement, such as a play or a concert, but any harm done thus is nothing compared to the kind of thing that young girls are subjected to in the London season, for instance—girls palpably immature, and needing all the special care which adolescence demands, but thrust instead into an atmosphere of excitement and noise and sex and stimulating food and drink at late hours, all of which combine to spoil sleep, vitiate development, and prejudice, perhaps beyond recall, the chances of noble and complete womanhood in the future.

If pleasurable emotion may injure sleep, vastly worse is distressful emotion, especially of the kind which we call worry. Most of the disastrous work done by worry upon mind and body uses insomnia as its instrument. There are emotions which discharge their energy, and, though they are costly, the expenditure pays. But worry is literally "strangling." The choked emotion, without outlet, works havoc within the nervous system which produced it, and only too often wrecks this incomparable machine.

Above all, it does so by the simple but supremely effective method of preventing sleep. The patient may eat and drink as he did—not less; probably he will drink more, and worse; but if the nervous system cannot get the essential condition of its nourishment, which is sleep, none other will avail it, and all disasters are possible.

There is a sleeplessness which is patient and resigned, and not restless. Many people who have to bear insomnia do so with wisdom, which enables much of the nervous system to sleep even when consciousness is not abolished. But the insomnia of the worried man is impatient, unresigned, and tossing, and that is the kind that kills—sometimes the body, oftenest the mind. All this may be obvious enough, but it is a great point gained if we realise where the difficulty actually lies, since thereby we save ourselves the labour of beating the air—and the pillow.

The Appalling Failure of the Use of Drugs for Insomnia

It is a great point gained to realise that insomnia due to emotion, and, above all, to the unpleasant emotion we call worry, can safely be controlled only by removing its cause. The narcotics in general have no field of usefulness in this connection, whether alcohol, opium or morphine, chloral, chloralamide, paraldehyde, sulphonal, trional, tetronal, "nepenthe," or even veronal. Each and all of these may have its use elsewhere. The last, perhaps, has its place (but only under continuous and responsible medical guidance) for periods in the treatment of pure insomnia due to causes such as grief, which cannot be removed, though time will relieve them. But for insomnia due to worry, not less than for insomnia due to indigestion, these drugs are worse than useless, as will be any future hypnotics that may supersede them. There are no words in which to make this warning too strong and effective.

Insomnia is never more terrible than when it leads to disaster by means of drugs. Too often the patient now loses his power of resistance to any narcotic. He may have been a teetotaller or the most moderate of drinkers before—he becomes a drunkard now. The drug may not be alcohol, but may just as well be any of those we have named, and more besides. One and all, these are essentially narcotic drugs, though most of them appear to have an initial stimulant action, which is really not stimulation, but the consequence of narcosis of the highest, most susceptible, controlling, checking areas of the brain. The poor fellow cannot sleep, he has miserable emotions, and naturally he welcomes the drugs which narcotise his emotional centres and induce sleep. Too often there are none to tell him, in time, that the end thereof is death; too often the venal adviser is at hand who commends such things, with their immediate and obvious success—and their ghastly ultimate failure.

The Profound and Lasting Wisdom of Shakespeare in Discussing the Drug Question

Shakespeare, the all but omniscient, gave us the wisest advice when he made Macbeth, without any hope of answer, ask his wife's doctor for "some sweet oblivious antidote" to "cleanse the stuff'd bosom of that perilous stuff which weighs upon the heart." The wise doctor answers, "Therein the patient must minister to himself"; and Macbeth, no less wise, concludes: "Throw physic to the dogs; I'll none of it." To-day we have many forms of physic which daily save lives: quinine, diphtheria anti-toxin, foxglove, mercury, "606," and such like; but we have nothing, and never will have, which enables us to qualify Macbeth's advice in all such cases of insomnia due to worry. Throw physic to the dogs—ancient alcohol, modern sulphonal, and the newest "oblivious antidote" of the synthetic laboratories of Germany, one and all. "Therein the patient must minister to himself."

To Refrain from Worrying About not Sleeping is Often the Way to Sleep

The practice of the best physicians to-day justifies the statement that the fashion with which doctors in the past, and too many practitioners, less eminent, to-day, have prescribed and recommended alcohol, chloral, sulphonal, and their like, in the face of the results and of the laboratory evidence, in these cases of worry and insomnia, will one day, and that not distant, be quoted to the dishonour of the present time, as doctors now quote the practice of their predecessors with other drugs, in indiscriminate bleeding, in the hothouse treatment of consumption, in the use of similarly noxious chemicals to

reduce fever, and in the " treatment " of the insane.

One last point on this matter of worry and sleep, before we turn to the physical aspects of insomnia. Our advice is specially applicable to elderly people, but it is relevant to all cases. It is that if one cannot sleep, knowing by experience, for instance, that, waking up in the morning unduly early, there is no hope of more sleep, it is better not to attempt the impossible. In any case, sleep seldoms yields to direct assault and battery. Further, to worry about lack of sleep, to toss and turn and try, and toss and turn and try again, is to remove oneself so much further from the state of rest which is desired. It is better to cultivate a little philosophy. If one cannot sleep and must do something, by all means one should read. It costs you far less in life and emotion frankly to give it up, and read at your ease, than to knock your head against the stone wall of your pillow.

If Sleep does not Come, why not Rest Contentedly or Employ Yourself Usefully?

Better still, but much more difficult, is the practice commended by Dr. George Keith, the famous author of " A Plea for a Simpler Life." He and some few sensible and self-controlled people like him achieve the feat of lying quietly and even contentedly in bed for hours at a time when they should be asleep, where other people would be worrying, disgusted, or furious. If a man, lying awake in bed, has muscular rest, sensory rest, and emotional rest, he is perhaps not very far from profiting as much as if he were asleep altogether. But if one cannot attain this second best, take the third best, which is some quiet and satisfactory occupation, rather than the worst, which is to exhaust yourself in the fight for repose.

The Bunch of Nerves Behind the Stomach that Resents Pressure

Of equal rank with worry as a psychical cause of insomnia is dyspepsia as a physical cause—pain being excluded from our present consideration. Anyone who is a bad sleeper, or who strikes a patch of bad sleeping, should suspect indigestion in the absence of any other obvious cause, for this is by far the commonest. The same disturbance which produces nightmare may just as well interfere with sleep altogether.

Behind the stomach there lies a great mass of nervous tissue, called the " solar plexus," or " abdominal brain." It is this which disturbs us when we are hit " in the wind." An uneasy stomach troubles the solar plexus and makes an uneasy head, producing either nightmare or insomnia.

All the more likely is this to happen if we adopt the bad practice of sleeping on the back, instead of on one side, for the pressure of the stomach, loaded, or in motion, or both, upon the solar plexus is obviously greater when we lie on the back. We may be quite unaware that we have dyspepsia, for the only symptoms may be our poor sleep, and perhaps a dirty tongue in the morning. It is quite a mistake to suppose that dyspepsia involves pain, for there are many forms of chronic " atonic " dyspepsia, due to lack of tone in the walls of the stomach, which involve no pain, but are quite sufficient to impair sleep, and therefore to prejudice the general health.

The treatment of all such insomnia is to *remove the cause.* To take hypnotics, weak or powerful, which have a way of sending the digestion to sleep when it should be active, and which do not touch the cause at all, is folly, and involves the price of folly. The chances are that we may require the skill of a doctor in such cases, but we can also do a good deal for ourselves. It is most probable we require less food. The first need for nine sleepless people out of ten is to cut down—probably not *quite* to abolish—their last meal.

Stimulating Beverages which the Sleepless Should Carefully Avoid

There should be a clear three hours between anything like a heavy meal and the time of sleep. In the course of this interval the stomach should have distributed its contents, or nearly all of them, to the bowel, and then one may expect to sleep with a stomach which is both empty, or nearly so, and motionless—a very different matter for the solar plexus from the case of a stomach that is weighted by its contents, and is actively churning them to and fro.

Everyone should know, what experience has taught many, that true cerebral stimulants like tea and coffee should be avoided in the latter part of the day by those whose sleep is precarious. Cocoa need scarcely be feared, though it belongs to the same category, but tea and coffee contain a powerful principle, belonging to the group called alkaloids, which is known as caffeine or theine (they are two names for the same thing), and which directly causes wakefulness, and has no ultimate hypnotic action, like other so-called stimulants. Really bad sleepers, and people who are highly susceptible to this drug, should avoid tea and coffee altogether.

Coffee also contains a volatile oil which upsets the digestion of some people, and attacks their sleep in that fashion; such people may be able to drink tea with impunity, but cannot sleep after coffee. Alcohol is a narcotic or hypnotic in its essential action, but it is not to be commended as a hypnotic, either for the young or the old. The personal experience and teaching of such illustrious and nonagenarian authorities as the late Dr. George Keith and Sir Hermann Weber is entirely opposed to the use of alcohol for insomnia in the old.

Ideally, the reader will observe, we wish to avoid alike the substances which awaken the brain, and also those which artificially lull it; for under such conditions we should expect to give the brain its best chance of attaining its own internally governed health, and maintaining its own internally-governed rhythm. Thus we may look rather askance, in these cases, at even such relatively innocent and often useful stimulants as beef-tea and strong soups—at any rate in the latter half of the day. These should really be put on one side, like tea and coffee.

How Touch Sensations and Unduly Stimulated Sight may Drive Sleep Away

In order to sleep, we require the least possible disturbance of the brain by stimuli, either from within or without. Worry and dyspepsia offer contrasted examples of stimuli arising from within, and jogging at the brain when it wants to rest. Touch sensations from without often suffice to keep us awake.

The feet must be warm, the skin must be warm, but not too warm. When we are too hot in bed, the flushed skin becomes over-sensitive, and sensations derived from it keep us awake. We may lighten the bedclothes, and catch cold. A better plan is to get up and sponge the face, and even the whole body, with cold water, and then lightly dry the skin and return to bed. The removal of perspiration removes the cause of irritation, and very often the getting up and the temporary cold offer a hint to the brain-centre which controls the distribution of blood. Many people are grateful for the foregoing advice.

Morning insomnia due to the break of day is a kind of absurdity when coupled with the fact that we stayed up with artificial light for some hours the night before. Failing any change in general practice, or even the adoption of the Daylight Saving Bill, we have to accept the situation; and many poor sleepers can get relief by using "photographic blinds" for their bedroom windows. Most dreams are visual, though by no means all, as we shall see; and their visual character shows that the brain-centres connected with vision have been unduly stimulated before sleep, and so made specially sensitive when the solar plexus, for instance, sends up irritating messages to the brain.

Probably this congested or excitable state of the brain-centres of vision is due not only to reading and writing, but also to the too brilliant lighting of our living-rooms at night, especially since artificial light can never have the same hygienic qualities as natural light. Almost the only good feature of the modern fashionable dinner, with its waste, luxury, bad ventilation, over-eating, and lateness, is the confining of the light to the table alone.

The Noises of Cities as Spoilers of Sleep and Promoters of Dreams of Hearing

Sensations of sound are equally undesirable during sleep; and so is excessive stimulation of the hearing centres before it. Many people thus have to beware of music late at night. There is such a thing as ear-strain, and, unfortunately, we have no earlids—probably, as the present writer suggested many years ago, because it is necessary for the sleeping mother's ears to be readily accessible to her baby's lightest whimper. The noise of cities is disastrous in persuading people to close their bedroom windows; and also in spoiling sleep and inducing dreams of hearing, which are said to be becoming as common as dreams of vision, in consequence of the increasing ear-strain of the present day.

Dr. Hyslop, formerly the superintendent of Bethlem Royal Hospital, has confirmed the opinion of another distinguished authority, to the effect that the number of people with nerve weakness who suffer specially from "irritable weakness" of the ears, rather than the eyes, is increasing; and all who realise the importance of sleep and of the open window are bound to protest continually against the increasing noise of the modern city.

Wanted a Crusade Against Noises that are Unnecessary, or Unnecessarily Loud

The only practical suggestions that can be made here are two: first, that we should join in the formation of public opinion against unnecessary noise, especially at night; and second, that, instead of the dangerous practice of closing the bedroom window, we should employ cotton-wool or other ear-plugs, which are safe, effective,

and convenient. As regards the former point, physical and physiological experiment prove that sounds of low pitch have relatively short range. All noises purposely made by motor-cars ought to be of low pitch, being then perfectly effective at the short range which is alone required. The high-pitched notes and the new noises that are not notes should be forbidden by law, whether by night or by day.

Those who like warm baths should take them at night. They must not be so hot as to leave the skin irritable ; but short of that they soothe, and are definitely sedative, in the main, probably because they withdraw blood from the brain. Nor is this the only way in which the skin may be employed for purposes of sleep. The soothing effect of gentle stroking, say on the forehead, is felt by many people ; and this is utilised in massage for insomnia, often a most useful and effective remedy.

A person suffering from neurasthenia or nerve-weakness, and unable to sleep, is usually debarred from much or any exercise, for the nerves will not stand the work involved; and that, in itself, makes sleep more difficult.

Hypnotism and Rest-Cure Isolation as Hopeful Remedies for Insomnia

Here the warm bath at night, and skilful massage, may be invaluable. The massage gives the muscles a kind of exercise without calling upon the resources of the nerves. But it is highly important that the masseur or masseuse be not irritating to the sleepless person, or the result will be far more harm than good.

Hypnotism has proved itself, as we have already noted in passing, a valuable and safe remedy in many cases of chronic insomnia. The treatment may require to be repeated at intervals of a few months, especially with hysterical patients—who, as a rule, are easily hypnotised. Neurasthenic patients, on the other hand, are usually refractory subjects ; and, of course, if the patient will not go under, the remedy is not available. But it is a distinct item in the armoury of modern medicine against insomnia, and many have reason to be grateful to the French pioneers.

The "rest-cure" in its original form, as introduced by a famous American physician, and called, after him, the "Weir-Mitchell treatment," is often very useful in insomnia. Its essentials are isolation, massage, and over-feeding, but the latter item may be much modified when insomnia is the essential trouble. The isolation is most important, and often succeeds in breaking an insomnia that threatened to be dangerous and yielded to nothing else.

Such are the chief resources made available by modern knowledge in cases of chronic insomnia. For insomnia due to pain other measures are required. Acute insomnia, such as that which we see in pneumonia, and in some forms of insanity, requires the help of drugs, and here the modern introductions to the Pharmacopœia may be invaluable. They do not pretend to treat the cause of the complaint, but, by preventing the loss of strength which insomnia involves, they may save the life or reason.

The Gravity of a Use of easily obtained Hypnotic Drugs Unrealised by the Public

But the last paragraph should lend weight to the essential tenor of the present argument, and to the reiterated warning with which it must close. The utility of hypnotic drugs in chronic insomnia is very small, and can only, if at all, be obtained by the skilful doctor who, at the same time, is vigorously attacking the causes of the trouble so far as he can. Of course, there exist black sheep in every profession, and there are, or lately used to be, doctors who obtain credit by the use of hypnotics in such cases. But the public is learning wisdom by bitter experience; and the present risk is mainly run by inexperienced young people who find access to hypnotics made easy by the resources of modern pharmacy. It is so simple to buy tablets of sulphonal or trional at the chemist's, and so easy to take them. The accessibility of veronal has lately led to calamities, and the public will not now find it obtainable from responsible pharmacists.

A Plea for Legislative Restriction Against an Ignorant Use of Dangerous Drugs

The secret with all narcotics is not to begin them. The type of drugs which are known to science as "neurotic poisons" are far too accessible to the public, and the time has come for one of two things. Either we must have much more stringent legislation than hitherto regarding their sale, recognising that these drugs may be dangerous, and should be scheduled as morphia and prussic acid are; or we must have an educated public, which knows the danger involved in their use, and sees the crass futility of it, even though it were free from risk, while the causes of insomnia remain untouched. These causes must be removed if we would attain almost the greatest of life's boons, which makes all its burdens bearable, turns work into pleasure and pleasure into delight.

THE AIRMAN'S VIEW OF THE EARTH: "THE CRINKLED SEA BENEATH HIM CRAWLS"

A PHOTOGRAPHIC SEASCAPE, WITH M. LOUIS BLÉRIOT MAKING THE FIRST FLIGHT ACROSS THE ENGLISH CHANNEL, ON SUNDAY, JULY 25, 1909

THE FLIGHT OF MAN

How He can Now Fly Twice as Fast as a Bird that is Not Helped by the Wind

NAVIES GRAPPLING IN THE CENTRAL BLUE

If one may judge by the third Exposition Internationale de Locomotion Aérienne, being held in Paris as we write, the monoplane is the flying-machine of the future. It looks like a gigantic insect. It has a long, fish-shaped body, often formed of hollow sheet steel, and steel is also used in the framework of the two wings. In some machines the wings are folded, insect fashion, over the body when at rest. The speed ranges from ninety or a hundred miles to forty-five miles an hour.

Monoplanes with a speed of forty-five miles an hour are built to carry five persons. Four passengers sit in a comfortable carriage in the fish-like body of the flying machine, and mica windows in the floor and in the sides enable them to look at the earth and the sky. The interior resembles that of a first-rate taxicab. On a seat in front, just like a chauffeur's, sits the pilot, and under his control is a hundred-horse-power engine which is directly connected with the propeller. This great monoplane is not an experiment, but a practical commercial touring-car, built by Blériot, the pioneer of Channel flight, and bought by one of the leaders of the art of flying.

The type of machine in which the brothers Wilbur and Orville Wright first soared into the air does not now seem to be in favour; it consisted of practically four wings, one set placed below the other, and connected by stays. A year ago it was generally thought that a biplane of this kind could carry more weight than a two-winged machine, or monoplane. It was admitted that the monoplane was faster in flight, but the common opinion was that for good, useful work the biplane was preferable. Now, however, in both quantity and quality the monoplane seems to be rapidly elbowing the biplane out of existence; and no machines are shown at the exhibition in which more than two sets of wings are used. Nearly all the old features of the biplane have disappeared, and most of the new machines which keep this name are really of monoplane design with a lower set of wings added. A speed of a hundred miles an hour is claimed for the best examples of monoplane and biplane, and some of the machines have actually carried in flight eleven persons.

Rising well above ten thousand feet in the skies, and travelling at the rate of ninety to a hundred miles an hour, the flying-machine has quickly become one of the most important of human instruments of warlike power. During the French Army manœuvres of 1911, it was used by a large troop of men, possessing the skill born of long experience; and they changed the conditions of warfare. No ambush was possible; every arrangement of the opposing army was discovered by the scouts in the skies, and communicated to their general. Had it been an actual battle against a country possessing a small, inferior body of airmen, and had the French aviators used bombs, and fought as well as scouted, there can be little doubt but that they would have proved a horribly formidable body of warriors.

For good or ill, the flying-machine has arrived. It costs less than a good motor-car, the price ranging from £250 upwards. Controlled by a trained man, it is much less dangerous to fly than is generally thought. As a rule, the higher in the air an aviator is, the safer is his position. Even if his engine or propeller breaks down, he can alight comfortably, providing that the accident does not occur when he is close to the ground. For his machine is essentially a glider, and in it he can glide at a speed of 150 miles an hour from the clouds to the field, shutting off his engine and trusting entirely to the management of his two artificial wings.

As a matter of fact, the aeroplane is wrongly named, and so are its various varieties—the monoplane, the biplane, the triplane, and the multiplane. There are no planes in a modern flying-machine. The supporting surfaces are wings, shaped like the wings of soaring birds, with a curve underneath. The shape was worked out by Mr. Horatio Phillips in 1884, and it is now being generally adopted, after a quarter of a century's experiments in newer but less efficient ideas. The wonderful success recently obtained by the machine of a French aviator, Nieuport, who returned to Phillips's principle, seems to be mainly responsible for the general reversion to English ideas in the matter.

OTTO LILIENTHAL ON HIS GLIDER

A great deal of the science of the flying-machine was worked out in England. Indeed, it is now more than a hundred years since Sir George Cayley discovered the general laws of mechanical flight. Cayley clearly analysed the forces at work in supporting a large bird gliding with outspread wings through the air, and he conducted a series of experiments to show how a flying-machine could be made. He even constructed a machine which was perfectly stable and ascended and descended by means of a tail rudder. The only thing that stood in Cayley's way was the imperfection of the steam engine at the beginning of the nineteenth century. It would not give per pound weight the amount of horse-power which Cayley saw was necessary in order to work the machine. With wonderful insight Cayley remarked that a new prime mover might be invented in which a mixture of gas and air could be exploded under a piston, and he then let the problem of flight drop.

During the greater part of the nineteenth century, the development of the dirigible balloon distracted the attention of inventors from the more difficult and more important question of the flying-machine. In 1866, however, Mr. F. H. Wenham took up the study of the soaring power of birds, and made some exceedingly valuable contributions to the science of mechanical flight. He determined the form of the modern aeroplane, and he showed that the power needed to drive it through the air was much less than had been supposed.

The correctness of his views was established by the experiments of A. Pénaud in 1872. Pénaud was the first man to build a flying-machine that flew, but he had to use only small models, because of the old difficulty of getting a light but powerful engine. All that was wanted to make mechanical flight practical was the light motor which came with the motor-car. In principle, not much has been added to the work of Wenham and Pénaud.

Horatio Phillips carried on the work of Wenham, and changed the aeroplane into a winged machine. He took as a model the wing of a herring gull. Wenham had shown that the length of the supporting surfaces was more important than the breadth. The edge which is presented to the wind does nearly all the work, and by making this edge longer more support is obtained. Wenham, however, used real planes instead of wings; that is to say, the supporting surfaces were quite flat, like the lid and bottom of a long, narrow box, connected by stays. Phillips curved them in exactly the form of the wing of a herring gull, and he patented his invention in 1884.

Some years after Phillips's work, a German, Otto Lilienthal, also discovered the advantage of the wing form. Too much credit has been given to Lilienthal for making discoveries which Phillips actually patented years before the German took up the problem of flight. For instance, in the last book published on the subject it is stated that "Lilienthal demonstrated that if an oblong surface were curved, the loss

in power of the rear half of a plane might be overcome; and the investigations of Horatio Phillips and the Wright brothers have confirmed his opinion." This is unjust. The real fact is that Phillips worked out the idea of the wings of the modern flying-machine; and if he only possessed in law the same rights in his invention as an author possesses in the books he writes, he would now control the master-patent in the science of mechanical flight.

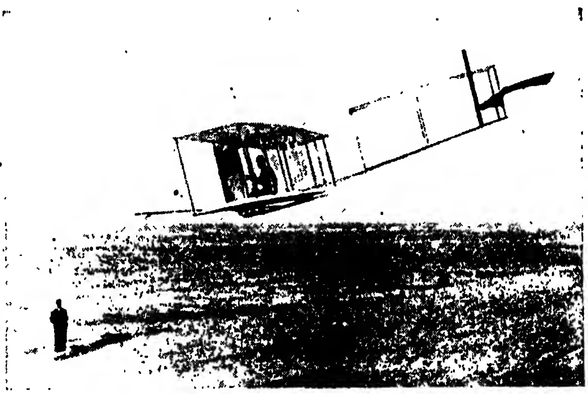
All that Lilienthal in Germany, Captain Ferber in France, and Octave Chanute and the Wright brothers in America did was to practise gliding with the wing-forms first discovered by Phillips. While these preliminary flights by the force of gravity were being conducted in England, Germany, France, and America, the petrol engine of the motor-car was being developed. No original invention whatever was needed to fix the petrol engine on to the flying-machine. It was merely an international race in a fairly easy piece of engineering craft. What did count, however, and count in a vital manner, was practice in the art of gliding.

Lilienthal was the best glider of his day, and he fixed an engine on his flying-machine in 1896. But while he was testing a steering arrangement he got caught in an awkward current; his machine was overturned, and he fell to the ground and broke his spine.

In England, Pilcher was also on the point of working his aeroplane by a motor, when one of the ribs of the machine broke during a flight in 1899, and he fell thirty feet, and was killed. Pilcher's work was very valuable. He gave the flying-machine its wheels, which lessened shock in landing, and added to the convenience of transport. He also showed that when the wings were given too V-shaped a form the machine would be upset by a side-wind.

In 1898, Captain Ferber, of the French Army, asked his Government for funds to fix a motor and a propeller on the aeroplane with which he had learnt to glide. The French Government, however, refused to provide the money. Thus the field was left clear for the Wright brothers, who were directly inspired by the work of Lilienthal. Advised by the fate of the pioneers of mechanical flight, the two American engineers went forward with extraordinary caution. For years they kept merely to gliding, though the engine for which all aviators had been waiting was ready to their hands. They knew what had killed Pilcher and Lilienthal, and they were resolved to obtain more control over their machine before fitting it with an engine. What they required was a more flexible wing: they wanted to be able to move just one part of the tip of one wing, in the simple way that a bird does by the graceful movement of a single plume.

The problem was easy of solution; indeed, there are now several ways in which it has been solved. The Wrights owed their high position in the history of human flight not so much to the fact that they surmounted the difficulty as to the fact that they were the first to see, in a clear way, that the difficulty existed and was of vital importance. Let us try to understand what was the obstacle they discovered; if we do this we shall obtain a practical idea of the fundamental principles of mechanical flight which so long tantalised inventors.


THE WRIGHT BROTHERS' GLIDER IN FLIGHT

Lord Kelvin was one of the greatest men of science of the nineteenth century, and he was convinced he had mathematical proof that a machine which was heavier than the air could never be made to fly. It certainly does seem extraordinary that a huge mechanical beetle, with a heavy engine, a long steel body, and wings made of a framework of steel covered with rubbered cloth, should now be able to fly above the clouds at twice the speed that the swiftest bird can attain without a wind to help it.

There is a great deal of exaggeration in the common idea of the speed of birds in ordinary flight; and it is only during the last twelve months that a series of scientific observations and experiments has been made in regard to the subject. It is possible, when certain birds are flying in a strong,

high, steady wind of fifty miles an hour, that they may use this and travel themselves one hundred miles an hour. But the maximum speed of birds in ordinary flight, without any favouring wind, does not exceed fifty miles an hour. Man, however, can now sweep through the skies, with no help from the wind, at ninety miles an hour; and there are some machines which are calculated to give him a speed of ten miles an hour more.

The aeroplane is really a kite with an oil engine attached. An ordinary kite is pulled against the air by means of a string. If a wind is blowing against the kite, a boy has only to pay out string, and his toy will soar in an admirable manner. If it is a windless day the boy must run and drag the kite violently through the air before he can get it to rise even to a small height. What he tries to get, without knowing it, when he runs, is air pressure against the front of the kite. If a sudden gust blew in the direction in which he was running, the kite would tumble to the ground. There must be two forces acting against each other, such as, in this case, a pressure of air tending to throw the kite backwards, and a pull on the string tending to bring the kite forwards. The result is the kite then obeys neither force: instead of going backwards or forwards it soars upwards. An eagle is an animated kite without a string, and by its muscular power it keeps its wings outspread to the wind. The chief problem in mechanical flight consists in finding a substitute for the string, which will enable us to hold the kite in the proper direction. This substitute is discovered in an engine-driven screw-propeller, similar to that used in steamships.

A flying-machine is kept from falling because the upward pressure of air on it, as it rapidly moves, is greater than the pull of gravitation. Unfortunately, the force of gravitation is unvarying, while the amount of air pressure changes with every puff and gust of wind. Moreover, while the point in a machine in which the force of gravitation is concentrated remains constant, the point at which air pressure is concentrated varies throughout the flight.

A BRISTOL AEROPLANE OVER STONEHENGE

Now, the entire art of maintaining the balance of a flying-machine consists in keeping on the same vertical line the centre of gravity and the centre of air pressure. If the centre of air pressure is suddenly altered, the machine is capsized.

Even birds find it hard to retain their balance. Sometimes the hawk will be seen swaying from side to side as he soars, in a constant effort to steady himself, like an acrobat on a tight-rope. And sometimes a gust of wind will strike a bird on the top of his wing, forming there a centre of air pressure far removed from the centre of gravity. The bird will then completely capsize, and tumble some distance through the air before he recovers his balance. Seeing that the living aeroplane finds the feat of balancing a difficult matter, it is hardly surprising that men should have been killed in the endeavour to discover the secret of steady flight.

The fact is that a flying-machine has to maintain two kinds of balance. It must not dip forwards or backwards, and it must not tilt over to either side. The lengthways dip was not difficult to avoid; the tail of a bird and the tail of a kite served to indicate what was required. All flying machines now have some sort of tail. It consists of a fairly small horizontal surface fixed in the rear of the machine. Generally speaking, the farther back it is placed the greater is its steadying effect; but if it is placed too far back, what is called a "dead centre" will be reached. When a flying-machine is travelling in a correct position, its tail meets the air edgewise, and offers no resistance. If, however, the head of the machine tilts downwards, the upper surface of the tail comes into play. It rises up and presents

THE NEW MENACE FROM THE SKIES

AN ANTOINETTE MONOPLANE IS HERE SEEN FLYING OVER AMERICAN WARSHIPS AT ANCHOR

surface, and the air strikes against this and forces it down, with the result that the head of the flying-machine is forcibly tilted up by the pressure on the tail. If, on the other hand, a gust of wind throws the aeroplane upwards, the tail presents its under surface to the pressure of the air, which then drives it upwards, and in so doing succeeds in righting the endangered machine.

The Wright brothers, however, built their first machines without tails. They thought these appendages were useless. The mistake arose owing to the fact that the first experimenters used tails which were too small, and placed too close to the wings of the machine. Many of the difficulties that the Wright brothers first encountered in their early flights were due to the want of a proper tail on their machines. They had to practise, while flying, the dangerous art of maintaining a fore-and-aft balance by shifting their bodies with every see-saw movement of their machines. When their aeroplane plunged downwards, they drew themselves backward; when it reared up, they swung their own weight forward. The marvel is that they escaped the fate of Lilienthal and Pilcher. In all successful flying machines at the present time, the lengthways balance is preserved by means of a tail, and the Wrights now follow the fashion and fit one to their aeroplanes.

FOUR AEROPLANES RACING AT BELMONT PARK

The machines here seen in flight, reading downwards, are Wright and Farman biplanes, and Blériot and Antoinette monoplanes.

The Wright brothers accomplished something more important than discovering the principle of fore-and-aft stability. By the rough and ready acrobatic method of swaying their own bodies to keep the machine from see-sawing up and down, they worked their way into the heart of the grand problem of mechanical flight. Taking up the work of Pilcher and Lilienthal, the two American bicycle-makers began by building gliding machines. These were flying machines of the modern sort, but without an engine and propeller. Started on the top of a sandhill, they swooped through the air, the force of gravitation that pulled them slowly downward acting as the motive power. The Wrights soon found out that side-pressure produced by chance gusts of wind was the most perilous of all the factors against which they had to contend.

Lateral stability was the thing that had somehow to be obtained before the practice of mechanical flight became anything more than an expensive form of suicide. An almost imperceptible side current of air was sometimes sufficient to make the machine cant over and capsize sideways. The fact was that the wings of the machine were rigid, while the wings of a bird, composed of infinitely flexible feathers, are able to change with every change of air pressure. Thus it was a vital necessity to invent a wing with flexible tips. This the Wright brothers did by a method which is now universally known as wing-warping. They constructed wings with movable corners. A cable ran from the right corner to the left corner, and attached to the middle of the cable was a lever. By moving the lever, one corner was bent up, and the opposite corner was at the same time bent down. Now, suppose that the machine was heeling over to the

THE HORROR OF WARFARE IN THE AIR

A CONCEPTION OF THE FELL WORK THAT CAN BE DONE BY AN AEROPLANE DROPPING BOMBS ON A FORT

right, under the pressure of a side-breeze. The aviator at once bent up the right wing of his machine, and bent down its left wing. The right wing then offered more resistance to the air, and greater upward pressure was consequently exerted on that side. The result was that the machine was swung back to its proper position.

Then, however, another difficulty arose. The full pressure of the air was only being exerted against the right side of the machine where the wing had been bent upwards. This had the effect of making the aeroplane spin round and swerve from its course. A brilliant discovery of the Wright brothers enabled them to correct this swerving. They fixed on their machine a vertical rudder, which was worked by the lever that warped the wings. When a particular wing was bent up at the tip to resist a side-pressure of air, the rudder was thrown, by the same movement of the lever, over to the other side. The wind pressure on it balanced the pressure on the upturned wing-tip, and the general result was that the machine neither tilted sideways nor began to spin round.

A NEW PAULHAN-TATIN MONOPLANE THAT FLIES 90 MILES AN HOUR

Besides being useful in maintaining a lateral balance, the wing-tips and the rudder are employed in turning the machine. When, for instance, the corner of the right wing is bent up, the air pressure is concentrated on that side, and the whole machine swerves round. This operation is termed banking an aeroplane. The term is derived from the fact that the curves of railway, motor, and cycle tracks are banked so as to enable turns to be safely made.

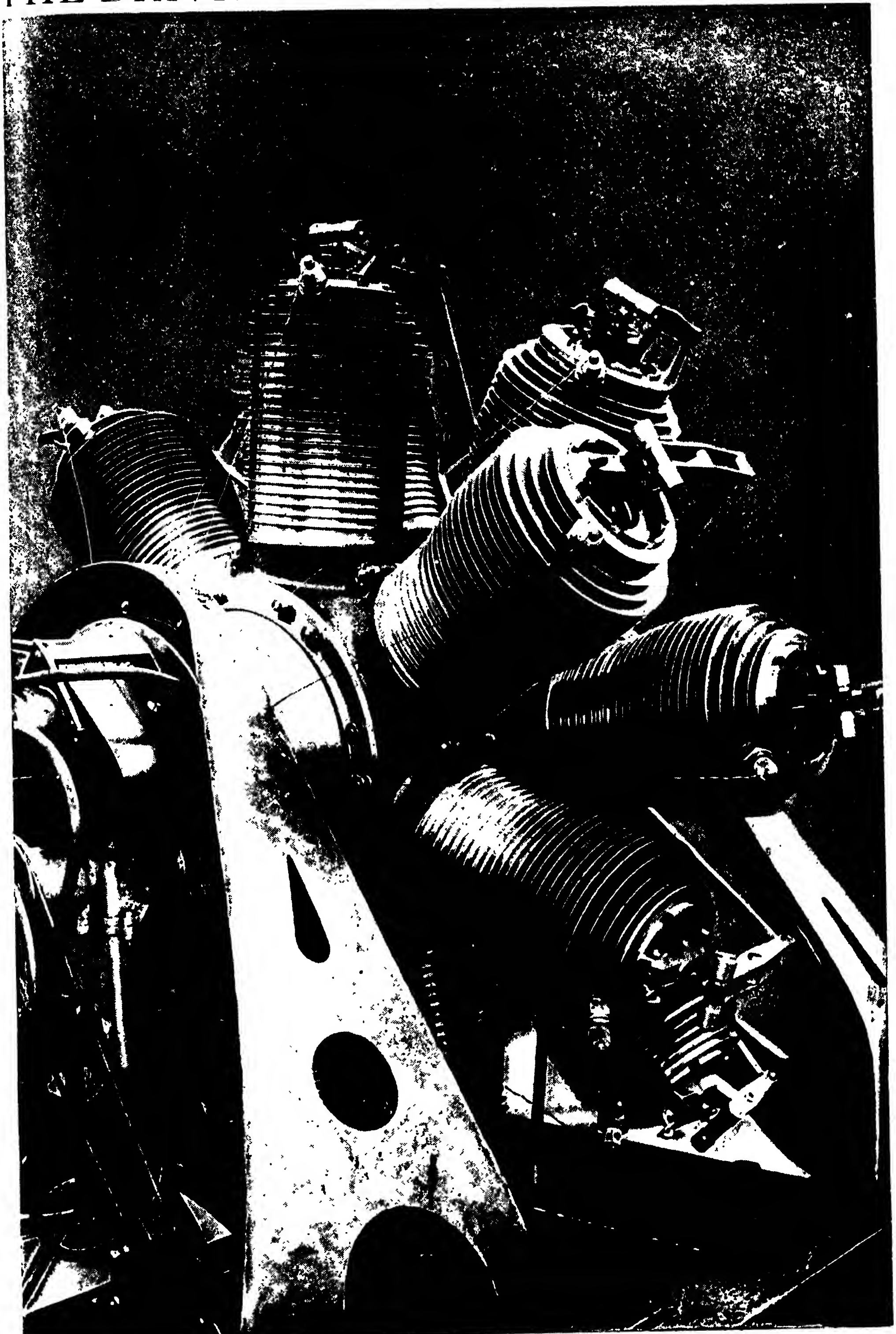
A flying-machine, however, requires another means of changing its course besides the wing-tips and the rudder which enable it to sweep in a curve. It must also be able to soar up to the skies like a bird. This is accomplished by means of a second rudder, which is usually called an elevator. As originally devised by the Wright brothers, this elevator consisted of a rudder projecting from the back of the machine, and formed of two flat surfaces connected together and worked by means of rods fixed to a second lever.

In nearly all the new machines the elevator forms a single surface, like the tail of a bird, at the end of the long, narrow body, and above it is fixed the thin, upright rudder, shaped somewhat like the fin of a fish. The rudder is worked from a pedal below the aviator's seat, and the elevator is operated by pulling backwards and forwards the pillar of the steering-wheel, while the rotation of the wheel itself warps the wings. A good machine of this kind can reach a height of about two miles above the earth, working up in large circles like an eagle until it fades from sight

Extraordinary power must, of course, be concentrated in these small machines to enable them to outfly the swiftest of birds. All along, as we have already seen, the whole problem of mechanical flight resided in the engine. No way of solving the problem was remotely discernible until 1876, when Otto invented his famous four-stroke gas-engine. This engine makes four strokes in creating a single movement of energy. In the first stroke the piston drives through the cylinder, creating a vacuum behind it, and drawing in a certain quantity of air and gas through a valve. In the second stroke the piston moves back, and the valves are then closed, and the mixture of air and gas is compressed. The third stroke is an explosion. The mixture is fired by an electric spark, and the piston is again driven forward. It returns in the fourth stroke, and drives out through an open valve all the exploded gases. Attached to the engine is a heavy fly-wheel, which serves to keep the piston in motion on the return strokes.

Such is the engine that at last made the flying-machine possible. But instead of gas, which cannot be carried in large quantities on a moving machine, petrol was substituted. The petrol was sent into the cylinder in the form of vapour, and mixed with air, and exploded. Finely designed by

THE DRIVING FORCE OF AN AEROPLANE

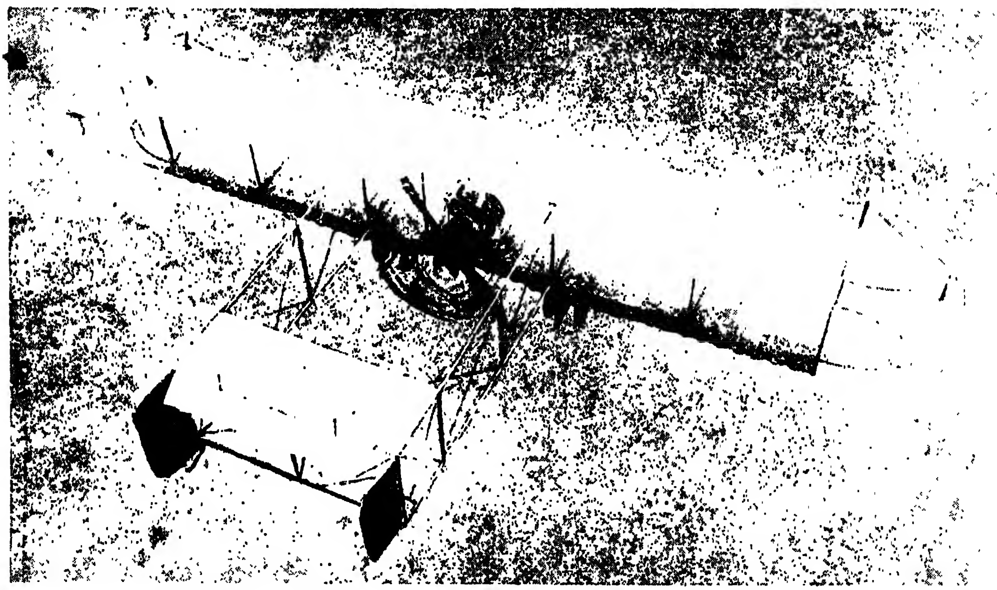


THE WONDERFUL GNÔME MOTOR, THAT REVOLVES TWELVE HUNDRED TIMES A MINUTE

engineers in connection with motor-cars and motor-cycles, the four-stroke petrol engine rapidly developed in lightness and strength; and in 1903 it was fitted with wings by the Wright brothers and sent up into the skies. At the present time French engineers are making the best engines for flying-machines; and it is largely owing to this fact that the French nation is in advance of all others in the practical art of flight.

The most celebrated of French motors is the wonderful little Gnôme engine. Many English engineers are inclined to think that its design is faulty, but there can be no dispute about its marvellous powers. It enables man to fly twice as quickly as the swiftest of birds. So light that it can be carried on the shoulder of a workman, it has a power greater than the combined continuous efforts of five hundred men; indeed, in some of the latest flying-machines its power excels that of one thousand men. Very curious is the manner in which this marvellous machine works.

Imagine a wheel without a rim, and with seven thick short spokes, which are hollow inside. In the hollow of each spoke is a piston working up and down, and the rods from each of the seven pistons are connected together on a small round piece of steel, that forms the hub of the wheel. The axle is also hollow, and through it is conveyed the petrol which explodes in the hollow spokes and drives the pistons. One after another the revolving spokes pass the firing-point; a spark flashes out, and causes the explosion. Down shoots the piston, and the piston-rod gives a turning movement to the central hub. This movement brings the next spoke into firing position, and there is another explosion of energy, driving the hub still farther round. After each explosion the spoke which has passed the firing point discharges its exhausted gases, draws in a mixture of air and petrol, and prepares for the next explosion.



THE BALANCE PROBLEM—A NEW BIPLANE WITH STABILISING PLANES THAT WORK AUTOMATICALLY

So far there is nothing strikingly new about the action of the Gnôme. Instead, however, of the hub of the wheel of exploding cylinders being connected with the axle, it is quite distinct from it in the new flying-machine motor. The axle never moves, but the spokes and the hub whirl round by themselves, like a fan, at the enormous, and indeed almost incredible, speed of twelve hundred and more spins a minute.

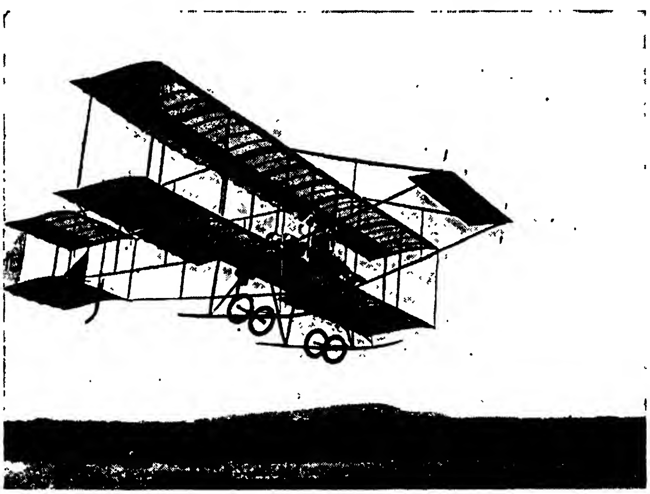
Attached to this whirling hub is a propeller, sometimes made of wood and sometimes of metal, and often with two long curved blades like the screw of a steamer. Usually the propeller projects from the head of the flying machine, adding to its weird, insect-like appearance. It is doubtful if, from a scientific point of view, a position in front of the machine is best for the propeller, but it has now been generally adopted for reasons of convenience in the engineering work. A head propeller draws the machine along; a tail propeller, on the other hand, pushes it through the air.

AN ANTICIPATION OF AN AERIAL POST

Mails have already been carried by aeroplanes; and in this picture is depicted a possible future scene of a huge air-bird about to pick up a mail-bag from a tall steel tower.

The whirling blades suck the air in from the front and cast it backward, creating a terrific little tempest. In the case of a head propeller, this tempest interferes with the action of the lower set of wings of a biplane, so in many biplanes the propeller is placed at the rear. Here, however, it cannot get a full feed of air. It is these two difficulties with the biplane which account for the present triumph of the monoplane. The single pair of wings of the monoplane is unimpeded in action by the wind from the propeller, and the round, thin, smooth, insect-like body of the machine offers very little resistance to the air. So monoplanes with head propellors and slim bodies built of wood or steel, and covered with a skin of steel or fabric, have now become the most useful and practical of flying-machines.

No dirigible balloon or airship can compete with them. Twice as speedy in actual flight, and much more than twice as safe in all winds, the great monoplane, which can carry a gun and some men, with a supply of bombs, is now the master of the skies. Terrible and swift will be the duel between the monoplane and the airship if ever a war breaks out in which these two new vessels of the air are opposed.



A FARMAN BIPLANE WITH A PASSENGER

Let us imagine ourselves on a war-machine, sweeping along at ninety miles an hour, with the earth three or four thousand feet beneath us. Suddenly we see on the edge of the sky a speck, which the telescope tells us is an airship. Her men cannot discern our machine yet, by reason of our much smaller size. First we have to find out if she is a friend or foe.

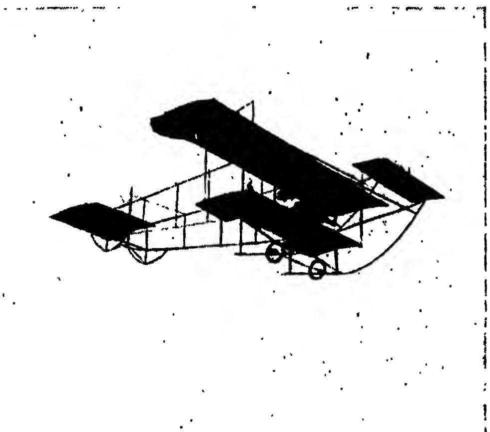
We must act quickly. Only twenty miles separate us, and at the speed with which the two vessels are approaching the distance will be bridged in about ten minutes. Heading our vessel upwards, we soar in rapid circles to a height of seven thousand feet, making in the direction of the strange vessel. Larger and larger she looms, and soon we recognise her as a foe—an enormous and yet beautiful creature, moving on serenely below us, unconscious of her peril. Suddenly she turns and her bow shoots up, and a stream of ballast falls from her cars. She has at last seen us, and now she is trying to escape from danger by an upward flight. Can she do it? we ask ourselves.

When her look-out first saw us we were seven thousand feet up, while she was only five thousand feet. Half a minute more, and if her captain and crew had not been alert they would have gone down without a struggle. But her men are finely disciplined and trained. Not a moment do they lose; yet it takes her some time to turn, and we are only a few miles away when she gains on our first level. Her guns ring out, sending at us a spreading fan of explosive shot, any of which would wreck our machine. But we are prepared, and we have swerved well out of range, and soared still higher into the heavens. It is now a race to the highest altitudes, where the human frame grows faint and drowsy in the strangely thin air. But we see with stern joy that the cold sky is wonderfully clear. There is not one cloud in which the great airship can hide herself from the imminent dangers of our mosquito attack.

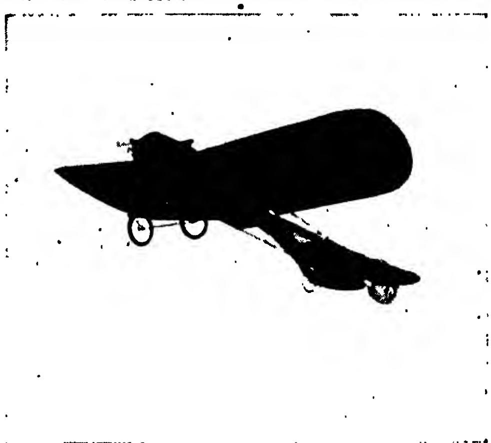
Minute after minute passes, and every minute the airship gains on us in height. Though our speed is much greater than hers on a level course, she is able to ascend more quickly by lightening herself. The ballast is pouring from her sides, and her crew at last throw over their petrol tins, and their clothes, and many of their instruments. Their only hope is to keep going up and up, trusting that our fuel may give out or our engine break down. But their hope is vain. We have fuel enough for several hours, and our Gnôme is going splendidly.

THE COMPETITORS OF CLOUDLAND

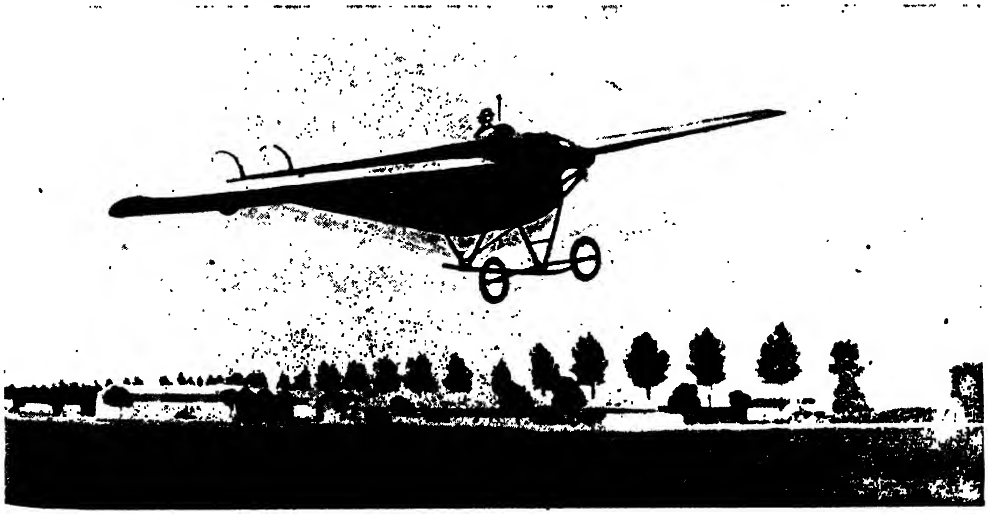
A RACE BETWEEN AN ANTOINETTE MONOPLANE AND A SIXTY-HORSE-POWER MOTOR-CAR



A SOMMER BIPLANE



A BLÉRIOT MONOPLANE



THE NIEUPORT MONOPLANE, WHICH IS HELD TO BE THE MOST SCIENTIFICALLY DESIGNED MACHINE

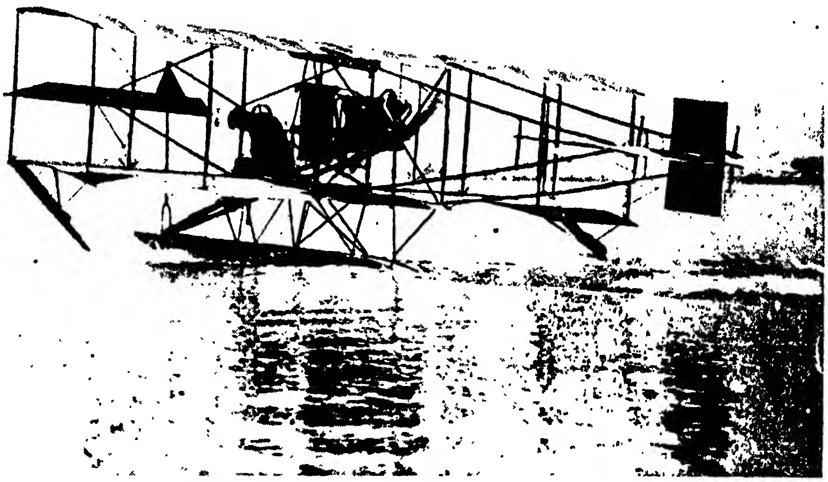
A NEW WAY OF SENDING FORTH THE DEADLY SCOUTS OF THE SKY

[illegible] of a biplane from a ship-of-war at sea. Sky scouts have since made good their return to the warship they left

It is only a question of endurance now. At the height we have reached no airship can have any reserve of fuel left; her engine will at last stop, and she will drift, a helpless mass, before the wind. Look! All her ballast is now gone, and she is beginning to fall. Still keeping out of range of her guns, our machine circles above her in large, eagle-like curves, and then, noticing the drop of the enemy, makes her battle swoop. Our pilot grips the wheel, his feet play on the rudder pedals, and in one long, swift dive the flying-machine passes over the top of the dirigible balloon, and then soars again upwards. Far below her the bomb explodes, and the mighty airship is no more.

to devise a flying-machine which will automatically maintain its stability in any kind of wind. Such a machine would be as safe to travel in as a ship. But though much has been done to keep the best of the latest machines steady, without any help from the pilot, it cannot be said that the problem of automatic stability has yet been satisfactorily solved.

Until this is accomplished the last and most wonderful invention of man will be mainly useful only in war. Very soon our most powerful battleships will have to be accompanied by destroyers designed to act as carriers and landing-places for the flying-machines which will probably take a chief part in deciding both the



THE CURTISS HYDRO-AEROPLANE ON THE SURFACE OF THE SEA

Perhaps some of her crew may escape by means of parachutes, but the blow has come so suddenly that they may not be prepared for it.

Terrible beyond all other battles will be the war in the air. The vessels cannot be captured; and, unless they are destroyed, their guns can easily wreck the machine that approaches to take them prisoner. So it will always be a fight to the death; and when the fight occurs between two flying-machines, the one that can rise higher and travel more quickly will be the one to conquer.

At the present time some of the most ingenious minds in the world are trying

naval and land battles of the future. Perhaps we shall then reach a point at which the instruments of war will be so destructive that any two nations using them will be mutually shattered.

Such seems the way in which half a million years of human warfare will be finally closed in a world-wide peace. Already it appears possible that a couple of men in a single flying-machine could wreck London or Berlin, Paris or St. Petersburg. Did not Tennyson predict in "Locksley Hall" that the horrible power of war-machines of flight would end in "the Parliament of Man, the Federation of the World"?

TYPICAL EXAMPLES OF SKY SCRAPER ARCHITECTURE MADE POSSIBLE BY THE USE OF THE LIFT

This photograph is by Edwin Levick, New York, and those on pages 1314 and 1318 are reproduced by courtesy of "Concrete and Constructional Engineering."

A REVOLUTION IN BUILDING

The Fœtid Slum and Hideous Sky-scraper Doomed by Healthy and Artistic Structures

THE WONDERS OF ARMOURED CONCRETE

NOTHING so clearly reveals the spirit of a race as the buildings which it erects. You can tell what the Greeks were from the Parthenon; what the Romans were from their masterful and majestic aqueducts; what the Arabs were from the Alhambra; what the mediæval Europeans were from the soaring cathedral spires which sang their souls in stone.

But, happily, you cannot tell what the English race now is from either the small or the large structures which its builders are still putting up in the old bad way. New forces are at work in our national life, and these forces are beginning to affect both our domestic and public architecture.

Though a plaster grin upon a skeleton of steel seems to be the highest combination of engineering skill and building craft that we can reach, these surviving monuments of a period of national disaster have no longer any significance. They are not constructed to endure, and we have now something much better to put in their place. Few persons yet know it, but science and art have again met in a workman's cottage in England, in a railway-station in Germany, and on a sky-scraper in San Francisco. From their meeting has been born a revolution in architecture, which promises to sweep away both the slum and the pretentious monstrosity which now passes for a palatial edifice. We are at last recovering from the strangest misfortune that ever befell a highly civilised race.

It is now about a hundred years since the English-speaking people fell, in regard to the sense of beauty, almost to the level of the least artistic of savages. The savage instinct for pattern, of course, varies greatly; but even when the work of primitive races seems to our taste to be ugly, there is still a feeling for decorative pattern about it. Sheer bad, meaningless design cannot be found in any handiwork of mankind before the age when the English nation was suddenly and strangely robbed of one of the chief qualities of the human imagination. No one knows yet exactly how the disaster came about. But it is clear that the extraordinary industrial revolution of the eighteenth century found us utterly unprepared. Vast new forces were abruptly placed in our hands by James Watt and other famous inventors. Instead of mastering these forces, we allowed them to master us.

It would be unjust to say that only the passion of greed has found expression in the monuments of the Victorian age in which the English race dominated the world by its industry, its colonising genius, and its wealth. But certainly the really characteristic buildings of that age—some of the houses of the working people and some of the huge structures in which they laboured amidst a clatter of machinery—are the most degraded and the most degrading works ever shaped by the hands of men.

The circumstances of the lives of millions of our working people have been such as no savage has endured. By starving the imagination of the race, by taking away from it all sense of beauty, we have created something that is worse than savagery or barbarism. The new thing that we have created is de-civilisation. Of this de-civilisation most of our modern buildings of every kind are shameful monuments. Our immense stacks of business offices, that parody all the historic styles of architecture, are somewhat worse than the ugliest of factories and the meanest of workmen's dwellings. The latter have, at least, a character of their own, even though it is a deplorable character. The modern palace of commerce is a soulless, lifeless thing, which vainly apes the spirit of some age

when brick and stone and mortar were used in an honest and purposeful way.

For good or for ill we are, generally speaking, an industrial people, and the factory is the characteristic building of our period. In the modern factory, modern methods of building are now often employed in an honest though tasteless manner. There is no pretence about this kind of building: it is a sound and scientific product of the age of iron and steel. In 1801, cast iron columns and beams were used in building a fireproof cotton mill at Manchester; and by the middle of the nineteenth century, girders and columns of iron were in general use in England for carrying up the floors of mills and factories. All this was a step in the right direction; but unfortunately there was no master builder in the civilised world with the genius necessary to make fine use of the new materials.

The French, it is true, showed some originality, and boldly used only iron in some churches and municipal buildings of Paris. But among them there was no Michael Angelo or Leonardo da Vinci ready to seize the opportunity for creating a new and authentic style. It was left to the Americans to show what could be done with iron and steel; and what they did with it we now all know.

The Architecture to Which the Spirit of Chicago Has Given Birth

Inspired wholly by the spirit of Chicago and New York, the American architect saw in the new materials only a quick, cheap, and easy way of making money. It is hard to say which was greater, the enterprise of mind he showed, or the passion for greed he expressed. Certainly the monstrous structures which he made by setting upright on the earth a steel bridge and plastering it with stone or terra-cotta, were wonderfully significant of the character of the cities in which he worked.

In both conception and execution, the sky-scraper is original. It manifests the best qualities, as well as the worst defects, of the American mind. For one thing, it represents an undoubted advance in the science of building, constituting indeed, until a few years ago, the only modern style of architecture with a spirit and a method peculiarly its own. It is a combination of the factory and the railway bridge; and this combination is made possible by one of the most ingenious and useful of modern inventions—the passenger lift. The lift has played a very important part in modern architecture. About forty years ago owners of large business offices and great hotels in the United States found that all the rooms above the fourth floor of their buildings could not be let unless an elevator service were established. Then with the introduction of lifts into office buildings and hotels, there came the easy possibility of erecting edifices with eight or nine storeys, instead of only five floors.

There were, however, considerable disadvantages in erecting stone or brick buildings of this size. The lower walls had to be made very thick and strong in order to support the immense weight of the superstructure; so valuable space was lost on the ground floor. The cost of construction was often £1 a cubic foot. Now, at the present time in England, one can get a small house of well-laid bricks and sound woodwork erected at a cost of about 7d. a cubic foot. This will show how extraordinary was the expense of putting up the first great American business palaces.

The Part Played in the New Architecture by Cheap Steel and the Lift

Yet they were profitable to build, because of the lift service which was provided in them. It was the lift that forced the pace at which the American sky-scraper began to rise in 1880; and the cheapening of steel by the Bessemer process supplied the new material for which the American architect was looking. The Home Life Building in Chicago was designed in iron, but just as it was about to be erected its architect thought of the new cheap steel, and with remarkable enterprise hastened to build out of it the first of modern sky-scrapers. Almost at the same time the architect of the Tower Building in Broadway, New York, was struggling with the problem of constructing an edifice ten storeys high on a plot of land 20 feet wide; and he, too, solved the difficulty by setting a steel bridge on end and thinly plastering it over.

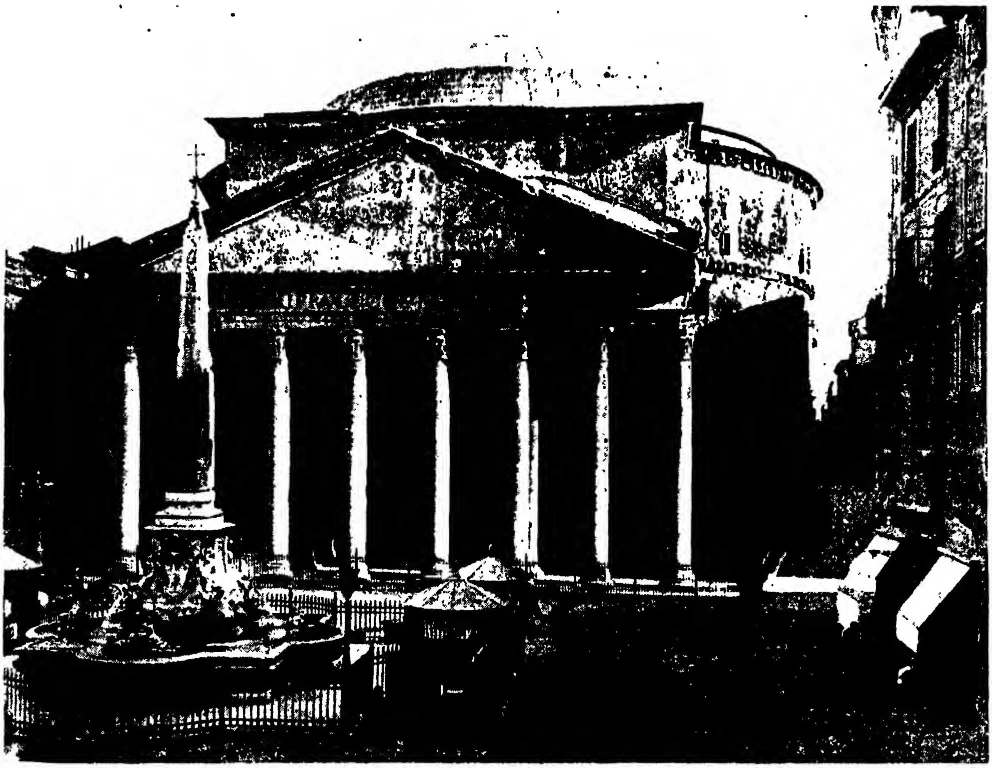
The Most Original Style of Building since the Gothic, and its Effects on Man

Such was the origin of the most original style of building since the development of the Gothic in the twelfth and thirteenth centuries. It reduced the cost of construction from £1 to 2s. a cubic foot. It sent up the price of ground at the junction of Broadway and Wall Street to £120 a foot. It turned the sky-line of New York into a horribly jagged sierra; and transformed the business part of the city into a series of sunless, windy ravines, filled with dark crowds of pale and neurasthenic fortune hunters.

Undoubtedly the American sky-scraper is a remarkable work of industrial science. The largest at present is the Metropolitan Life Building, which has a height of 658 feet above the pavement. It is arranged in forty-six floors, with non-stop lift services to the upper storeys. It contains 8000 tons of steel, and its height from the foundation is 715 feet. The Singer Building is 815 feet from the foundation, with 10,000 tons of steel work in it, but it only rises 612 feet above the pavement. A sky-scraper 909 feet high has been designed for the Equitable Life Insurance Company of New York, but this has not yet been built.

There seems no reason why the buildings of New York should not reach 2000 feet; for this height is possible under the building regulations of the city, which merely limit the weight of structures to fifteen tons per square foot of foundation. Steel is now cheap and strong enough to enable an American architect to frame a system of columns and beams and girders which would spread over a fairly large foundation the weight of an edifice double the height of the Equitable Building.

Perhaps, however, Nature is not so easy-going as the building authorities of New York. The sky-scraper architect has surmounted many difficulties. In the marshy land of Chicago he floats his immense structures on rafts; in New York he tunnels down to the rock, or sinks huge walls of cement to keep the shifting soil in its place. A series of disastrous fires has taught him that steel becomes one of the weakest of building materials long before it grows red-hot. So he now cases in all his columns, girders, and beams with some fairly fire-proof substance.



THE PANTHEON, ROME, A CONCRETE BUILDING THAT HAS LASTED NINETEEN CENTURIES

But, having done all this, he has still to face the same difficulty as the engineer who builds a bridge of steel or iron; or, rather, he has to face the same difficulty under more perilous conditions. He has to fight against the wind. In very strong gales the pressure that the wind exerts is enormous. Until the Tay Bridge disaster in 1879, engineers gave but little attention to the subject of wind pressure; and, although since that date much valuable information has been collected, we still know comparatively little about the action of wind on structures in the neighbourhood of other structures.

From experiments made at the Forth Bridge, it appears that a wind pressure of fifteen pounds to the square foot at a height of 50 feet may be increased to a pressure of sixty-five pounds a square foot at a height of 380 feet.

The earth has a dragging effect on the wind, so that the force of the wind greatly increases with its height from the ground. Again, the larger the surface the stronger is the pressure which the wind exerts on every square inch of it. On small surfaces the wind only acts in local gusts. When all these facts are considered, it seems probable that if the American sky-scraper continues to mount in the clouds, something will happen in a tempest in New York that will be far more disastrous than the fall of the Tay Bridge.

The Engineering that Battles with the Enormous Wind Pressure on Lofty Buildings

In present practice a wind pressure of thirty pounds to the square foot is usually provided against. The steel skeleton consists of three chief parts: columns, girders, and beams. The columns are continuous, and designed to offer easy connection of the girders; and on the rigidity of the connections depends the resistance of the building to wind pressure. The girders are bolted with hot rivets to the columns; and sometimes a stiffening piece of steel, called a knee-brace, is used to strengthen the structure and carry the wind presses from the girders to the foundation. In the Municipal Building now being erected at New York, many of the girders of steel are five tons in weight; they are the principal horizontal parts, and they are riveted to powerful columns, and across them is laid a network of steel beams. The entire design is very simple: it is usually termed a steel cage, and it exactly looks like it. The walls of stone do not hold up anything: they are merely weather shields—curtains that keep out the wind and the wet.

The Overmastering Importance of Quickness in the American Methods of Architecture

A sky-scraper in course of construction is an interesting sight. Work that would have taken an army of slaves weeks to perform under the lash in the days when the Pharaohs were building their pyramids is done in a few minutes by the monster-cranes which overhang the building. Girders which have required a team of twenty horses to drag to the scene of operation are swung high up into the air by a finger touch on a lever, and then lowered exactly on to the columns, ready for the riveters to bolt down.

Sixteen months only were occupied in putting up the steel work of the tallest of all sky-scrapers, the Metropolitan Life Building, with its forty-six storeys. Clothing the outside walls with marble merely took a little over three months. In the latest methods of steel-cage construction the stonework is started in the centre of the building. One gang of men works upwards, and another gang works downwards. In this way the clothing of the walls is done in half the ordinary time, for double the amount of men can be employed when the work is begun from the centre.

Quickness is everything in the construction of an American sky-scraper, for the owners are willing to pay highly for all appliances and methods which expedite the work. Every day's delay means an enormous loss of rent and a waste of ground-rent and capital. This is the main reason why the sky-scraper of steel is likely still to flourish in America, even though a sounder and more modern way of building has now been worked out and tested. Steel-cage construction means quick returns and large profits; and a series of stern restrictive laws will have to be passed—and, what is more difficult in the United States, these laws will have to be swiftly and generally enforced—before the steel-built sky-scraper disappears.

The Grandeur of Vehement Strength Expressed in the Sky-Scraper

As it is, the sky-scrapers of New York have made the centre of that city one of the most impressive places on earth. Beautiful the scene is not, but it has life and character, and it touches the imagination in a way that no streets of meaninglessly imitative buildings can do. In the titanic cliff-like ranges of steel-built towers is embodied a fierce wild energy of a living kind. The huge buildings have a real grandeur, the grandeur of explosive, lawless, vehement strength. In them is expressed the freest and most savage individualism ever existent on the earth, an inventiveness born of need and greed, a triumphant manifestation of the vast unregulated forces which have been working perilously throughout the civilised world since the age of the industrial revolution.

For the sky-scraper is a logical and living development of the English factories of the iron age. Only the wisdom and the traditions of our forefathers prevented it from springing up in London and Liverpool before it appeared in New York and Chicago.

NEW YORK'S PROGRESS SKYWARD

PLACING INTO POSITION AND RIVETING TOGETHER THE STEEL GIRDERS OF A SKY-SCRAPER

We, too, have many enterprising builders who would make huge fortunes by depriving their neighbours of light and air; but our common law stands in their way. The American people originally inherited our beneficent law in regard to ancient lights. One of their judges, however, decided that this part of the common law was an unjust restriction upon the rights of the individual. So it was set aside. Then any man who had a sufficiently large sum of money, and a sufficiently hardened conscience to do the ill deed, was allowed to run up anywhere tremendous overshadowing structures which robbed the people dwelling round about of some of the most necessary things in life.

Even at the present day, few or none of the people of central New York are aware how they have been robbed of their health. They put down their nervous disorder to the fever of business life. This no doubt has something to do with the matter, but the chief cause of their diseases is a microbe which only attacks the human body in cities from which sunshine and sunlight have been taken. Dogs and horses suffer from the same nervous complaint when they are set to work all their lives in the sombre canyons between the sky-scrapers of New York or Chicago.

The sky-scraper is a crime. No city is healthy in which the height of the buildings is greater than the breadth of the thoroughfare along which they are built. Many of the building regulations of our towns and cities are framed to preserve this proportion between the height of an edifice and the breadth of a street; but unfortunately these wise and splendid restrictions have not always been in force. It is absolutely necessary for the physical welfare of the people that the rooms on the ground floor of every structure should receive a certain amount of sunshine, especially in a cloudy temperate climate like ours. A room without sunshine is a chamber of death.

WORKING ON THE TOP OF THE NEW BANKERS' TRUST BUILDING, NEW YORK

A few years ago the directors of a prosperous London store resolved to convert their premises into a huge many storeyed building. Close at hand was a small tradesman living in a tiny house, and he looked with alarm at the high walls which began to rise around him and darken his shop. He wrote a letter of protest to the directors, but it was disregarded, so he grew angry and started a legal action. A few pounds were then offered to him for compensation, but his anger had by this time increased to such a degree that he did not care for money. He claimed his ancient lights, and insisted on the destruction of the high walls which darkened his shop. The directors became alarmed as the action went on, and offered at last a small fortune to the tradesman. He would not accept it, and a considerable part of the huge building had to be altered and kept low. Men of the stamp of this little tradesman, who are not to be bought for money, form the backbone of our nation; they keep alive the rights our forefathers won for us.

Though the American sky-scraper still seems to flourish, it really perished in 1906. With it went the steel-cage construction which, unhappily, is now being used in many new buildings in the United Kingdom. In April, 1906, there were about five hundred and twelve large buildings

blocks in that part of San Francisco which was tossed up and down by a terrific earthquake. The earthquake did comparatively little damage, ruining only five out of every hundred of the buildings that were destroyed. On the other hand, ninety out of every hundred of the edifices which fell, fell through fire.

In spite of all the precaution taken to fireproof the steel framework of the five hundred and twelve sky-scrapers, only the skeletons of thirty-six of them remained upright when the flame and smoke had passed away. Thus it was proved that the strength of steel is practically nothing, long before it is brought to a red heat. Covering columns and girders with a thin plaster of stonework is no secure protection against fire. Such was the lesson in modern architecture purchased by terrible suffering when San Francisco rocked and flamed into ruin about six years ago.

One remarkable building, however, stood firm and whole amid the wreck and ashes of 28,000 blocks and houses. This surviving building had been constructed of a new material used in a new and astonishing manner. It was made of armoured concrete, which has now been clearly proved to be the grand building material of the future.

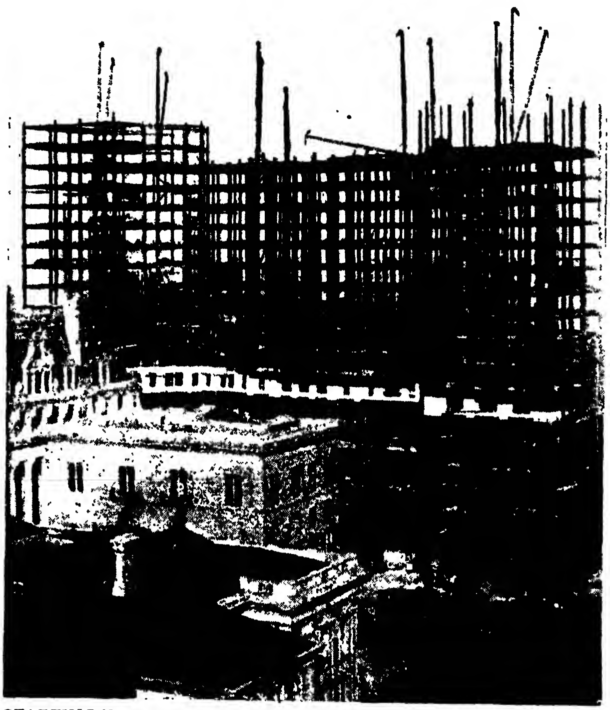
Armoured concrete is formed of Portland cement mixed with sand, and run into wooden moulds. The manner in which a concrete building is erected is more ingenious and wonderful than steel-cage construction. First of all, the wood is built up into huge hollow pillars and huge horizontal beams which are also hollow. Rows of wooden struts are placed under the beams as additional support. Then, in the hollow wooden moulds, thinnish rods and pieces of steel are inserted; and, after this, the concrete is poured into the moulds. Walls are built up by pouring concrete between two layers of wood; and floors and roofs are made by building up horizontal moulds of wood, and making a sort of upper pavement of concrete in them. When all the concrete is thoroughly dry, every piece of wood is removed, and scraped and cleaned and soaped for use on a new building.

STEEL WORKERS ON THE BANKERS' TRUST BUILDING WITH THE RIVER IN THE DISTANCE

Builders in concrete have an enormous expense at the beginning. Their wooden moulds have to be quite waterproof, and strong enough to resist the pressure of the concrete. They are made, however, in standard shapes, with a view to economy in taking down rather than cheapness in putting up. This means that they can be employed over and over again in the

erection of various buildings. They are fashioned somewhat on the lines of steel-cage work. There are moulds for columns, moulds for the girders that rest on columns, moulds for the beams that rest on the girders, and solid wooden struts which are placed under all the horizontal moulds. Many of the moulds are vast and heavy, and they are lifted into place by a giant crane which hangs over the building Pins serve to rivet the immense and intricate system of moulds together. When the pins are drawn out they leave holes in the concrete, which are filled in by hand.

In concrete work the carpenter and the designer of carpentry are the men of importance. The design requires, of course, the highest engineering skill. All the stresses have to be worked out, and the amount of steel and concrete carefully estimated, and a good margin of safety allowed for unforeseen accidents. It is not difficult to design a concrete building which will fall down, especially if the wooden moulds are removed before the sand and cement are thoroughly hardened. But if the design is good, and the material well mixed and well dried, a building of armoured concrete is stronger than any design of a similar kind made in stone, brick, or other material.



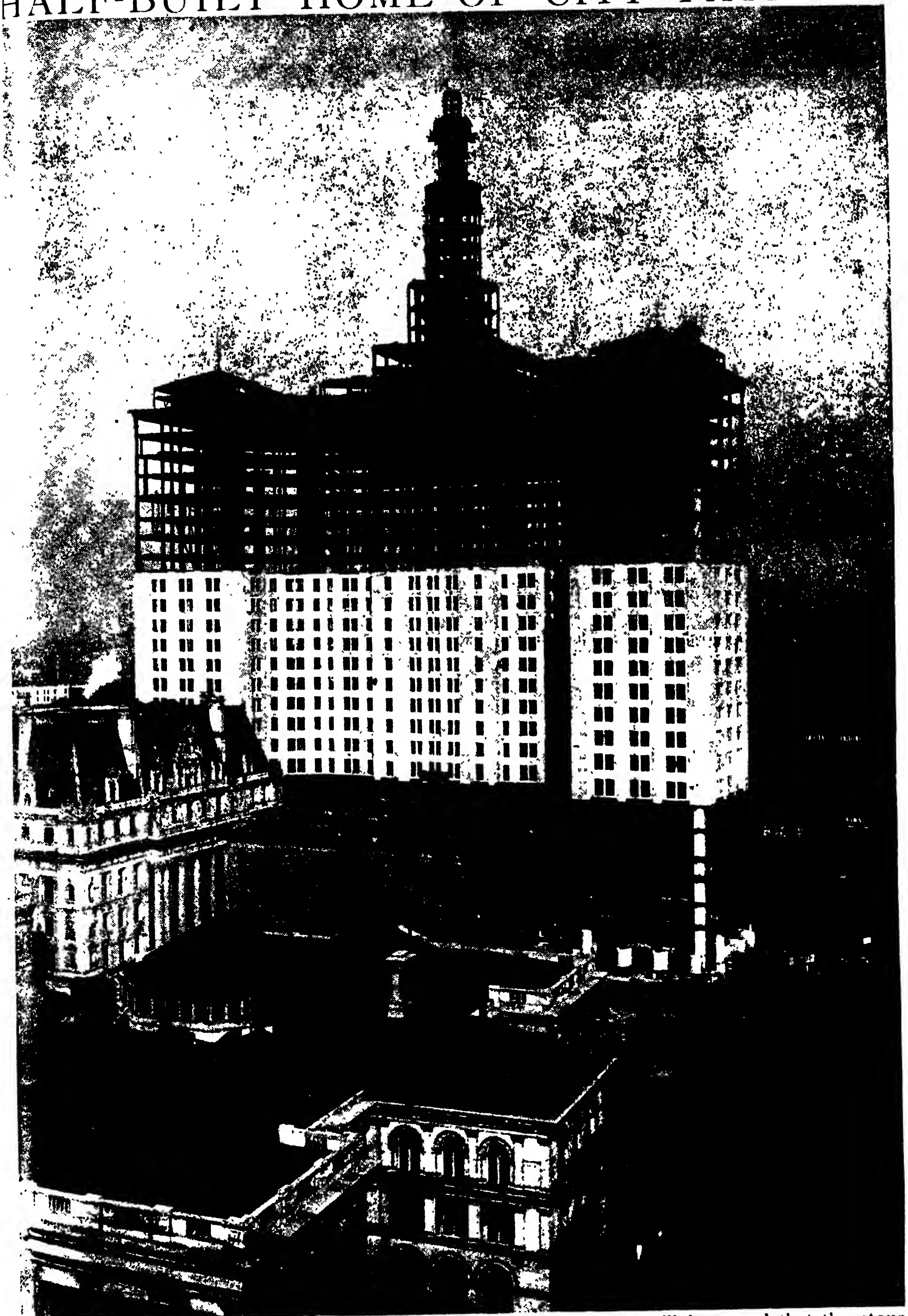
STARTING THE STONEWORK IN THE CENTRE OF THE MUNICIPAL BUILDING IN NEW YORK

The famous cement with which the Romans built works that still survive the wear of time is weak stuff when compared with English cement. There is some dispute about the invention of the new cement. It is usually attributed to Joseph Aspdin, a bricklayer born at Leeds in 1811, but lately a claim has been made for Isaac Charles Johnson, who was born in the same year of working-class parents at Vauxhall. Mr. Johnson died only two months ago at Gravesend in his hundred and first year. Probably the explanation is that Johnson, after a long series of experiments, managed to improve the Portland cement which Aspdin discovered when he was seeking for materials for the Eddystone Lighthouse. Aspdin called the mixture Portland cement by reason of its resemblance to Portland stone. In the original process, three parts of white chalk are mixed with one part of clay or river mud. These materials are placed in a wash-mill, where revolving cutters reduce the watery mixture to a cream. This is put in a reservoir to settle, and afterwards dried on hot iron plates and then burnt in kilns and ground to a powder.

Such cement is now often made of limestone and clay in a rotary kiln, or steel cylinder, which may be 12 feet in diameter, and 250 feet in length. The process is continuous in operation, the raw material being fed in at one end and discharged at the other end a finished product. During the passage of the material down the cylinder, perfect calcination is obtained by the injection of coal-dust by means of an air blast. The clinker is cooled and reduced into fine powder in a heavy iron mill. The strength of the cement depends on the fineness to which it is ground: from 90 to 96 per cent. of it ought to pass through a sieve containing ten thousand meshes to the square inch. Marl and clay, limestone and slate, can be used to make the mixture.

Like Roman cement, which is a natural mixture of lime and clay, English cement has the valuable property of hardening in

HALF-BUILT HOME OF CITY FATHERS



These are the new municipal buildings of the city of New York. It will be noted that the stone facing is begun in the middle of the building and is carried simultaneously up and down.

short time under either air or water. But while concrete made of Roman cement has only a tensile strength of thirty pounds and a crushing strength of two hundred pounds to the square inch, English cement has a tensile strength of two hundred pounds, and a crushing strength of a thousand pounds. It came into use about the middle of the nineteenth century, and at first there were numerous failures with it. As late as 1887, it was too imperfect for building docks, and objects made of it sometimes crumbled to pieces in twenty years. Even at the present day, it is necessary thoroughly to test the fineness of the cement used in concrete buildings. It is the best of materials when well made, and the worst when the grinding is not perfect. Good concrete has a unique quality. Instead of deteriorating with age, it grows stronger.

All concrete, however, has one serious disadvantage. It is good for columns, but bad for beams; it will resist compression, but it gives way under tension. Its resistance to tension is only one-tenth of its resistance to compression. So for many years it was used only in building dams, retaining walls, and foundations. Under favourable conditions a six-inch wall of concrete will cost less than a twelve-inch wall of brickwork, and will be stronger and more durable and damp-proof and fireproof. In short, concrete is the most desirable of building materials, if it were not for its small tensile strength.

MR. ST. LOE STRACHEY'S COTTAGES OF CONCRETE BLOCKS

The Romans got over the difficulty by reinforcing their concrete. In the centre of the slab they placed bronze rods, crossing each other, but more often they strengthened their coarse material with tiles. By this means the master-builders of the ancient world were able to erect structures of concrete which have withstood the stress and weathering of two thousand years.

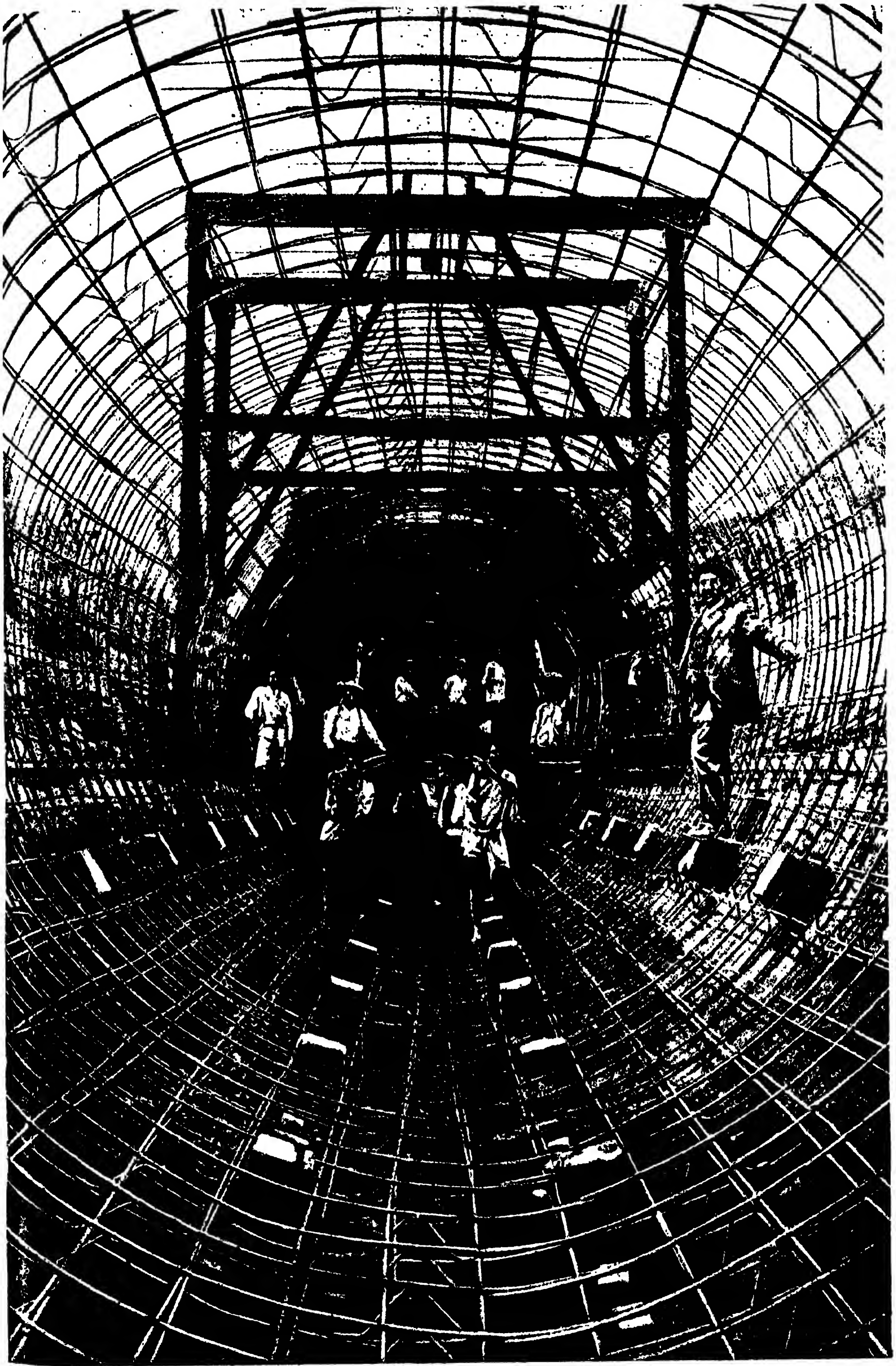
We began to recover their secret in 1824, when Joseph Aspdin invented the new cement. Then, in 1854, Wilkinson made fireproof concrete floors, in which were embedded iron bars that took the tensile stresses. With the cheapening of steel the value of the new material became generally recognised. Several men of science went thoroughly into the question of the distribution of stresses; and in 1897 a Frenchman, Hennebique, introduced a system of armoured concrete, by means of which there could be made small beams of very great strength. At the present day there is quite a multitude of systems of armoured concrete, and it is difficult to say which are the best. In all of them, steel rods, sometimes straight, sometimes crooked or fitted with angular side-pieces, are placed in the centre of a wooden mould, and surrounded with a mixture of cement and sand.

Concrete and steel go very well together; they have an adherence of a hundred pounds to the inch, and they are equal in their expansion under heat. All experience shows that armoured concrete is immune from bad atmospheric effects. The embedded metal is, moreover, thoroughly protected from corrosion and from fire. Thus it is superior to steel for the erection of bridges, as, instead of requiring constant attention and continual repair, it improves in strength for thousands of years. It has the additional advantage of being cheaper in first cost. Then, in comparison with steel-cage construction, armoured concrete gives more security against wind-pressure, besides being much more fireproof and dampproof.

Perhaps an architect would not be able to build quite so high with armoured concrete as with a steel-cage. This, however, is no real disadvantage, for the reasons we have already pointed out. The armoured concrete sky-scrapers of San Francisco, which withstood earthquake and conflagration, were already higher than any architect should be allowed to build in a city in which the health of the people is looked after by the building authorities.

Since the San Francisco earthquake, the Americans have become greatly interested in concrete; and practically all the building work of the Panama Canal is being carried out in the new material. In 1880 only

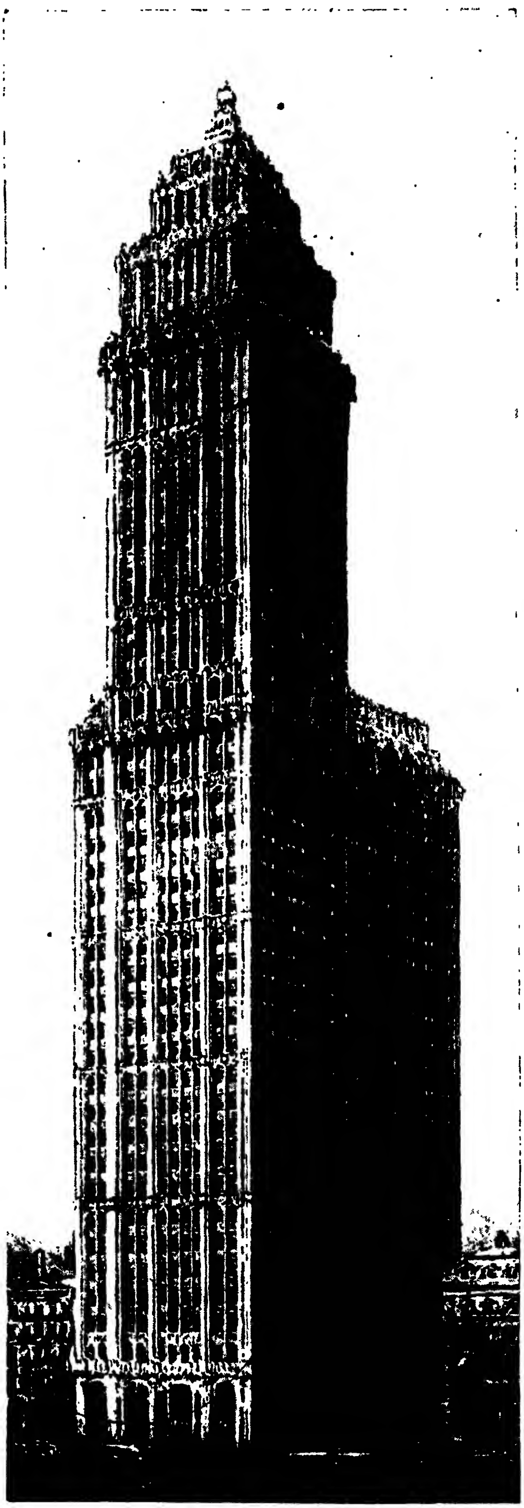
A TRIUMPH OF REINFORCED CONCRETE



This picture of a reinforced concrete conduit in course of construction in a Mexican city shows the elaborate steel rods that strengthen the concrete in which they will eventually lie. The concrete is kept in position, while drying, by the wooden framework seen in the centre of the picture. Subsequently it grows harder and stronger every year that passes.

forty-two thousand barrels of Portland cement were used in the United States, at a cost of 12s. 6d. a barrel, but in 1910 seventy-four million barrels were manufactured, and sold at about 3s. a barrel. While many of our building authorities have been hesitating to allow the use of armoured concrete, the Americans have applied the new principles of scientific management to concrete work, and produced some astonishing results. Mr. Frank B. Gilbreth and Mr. Frederick W. Taylor have created a system which is bound to affect the building trade throughout the world.

Mr. Gilbreth builds quicker than the quickest contract, and yet the strength and finish of his edifices are better than the masterpieces of the old Romans. The Lowell Observatory of Engineering at Boston is now a famous example of scientific management applied to concrete work. The secret of Mr. Gilbreth's success lies not only in the immense variety of standard moulds which he now possesses and uses over and over again, but in the way he deals with his workmen. Even in ordinary bricklaying they can now lay three or four times

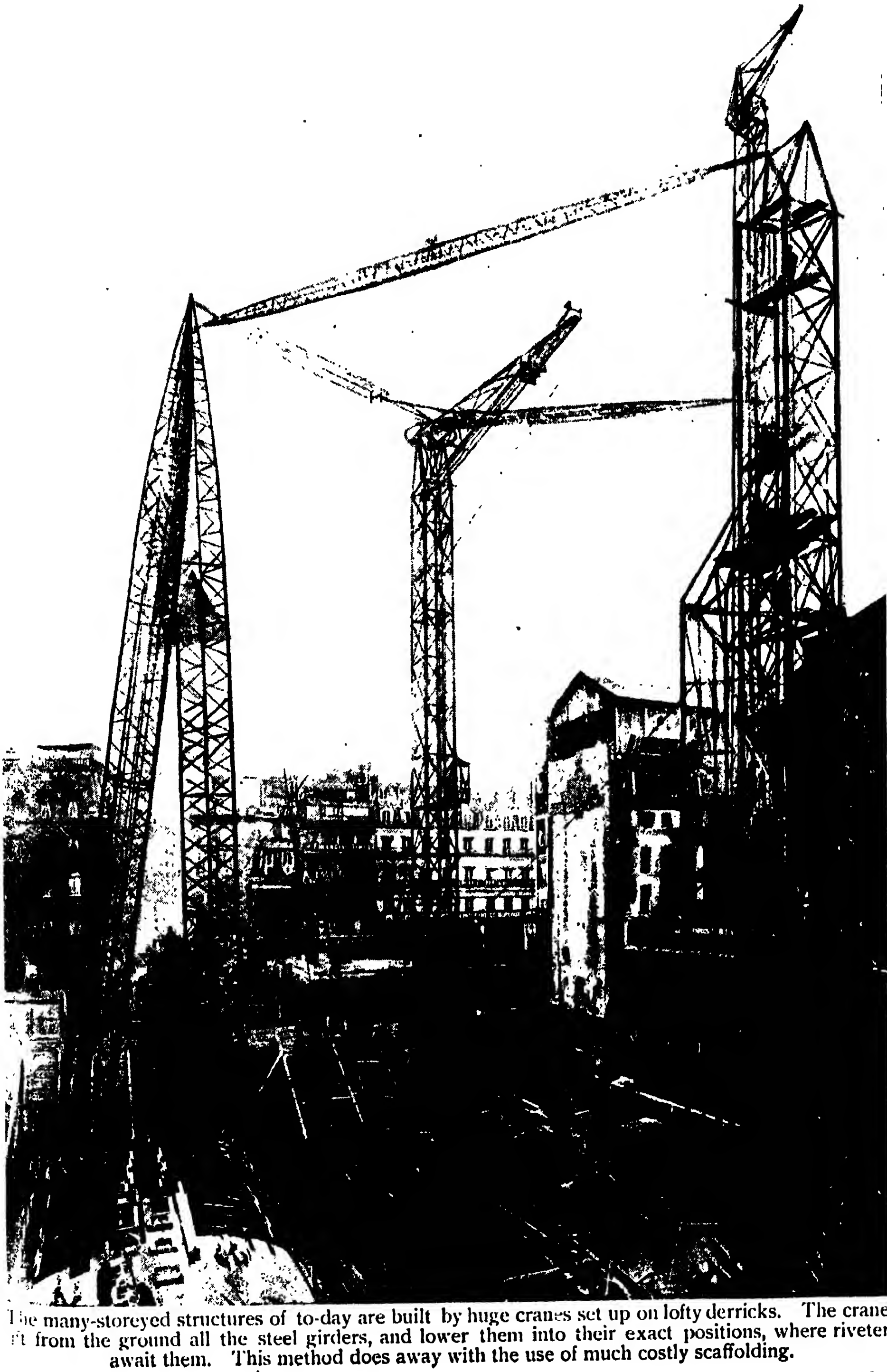


THE WOOLWORTH BUILDING OF FIFTY-FIVE STOREYS. 750 FEET HIGH

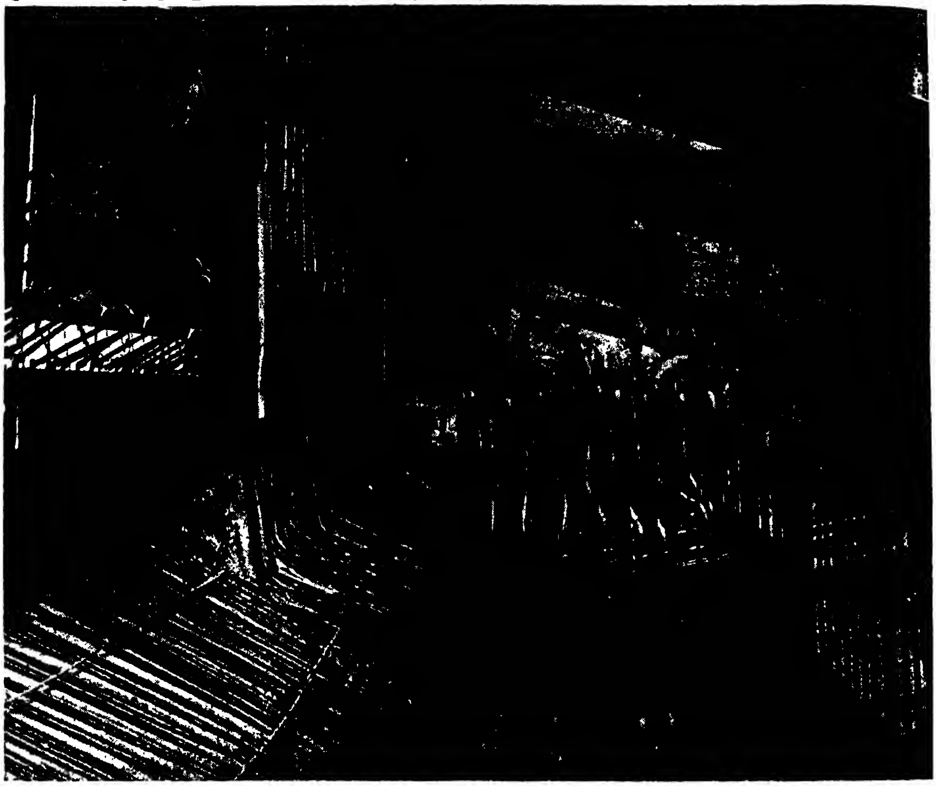
more bricks in a day than bricklayers can do on the traditional rule-of-thumb method.

And the miracle is that all this expeditiousness is accomplished with no additional muscular effort. New ways of doing the work and new labour-saving appliances enable a workman of the new school to do three times more building than an ordinary labourer, and then go home in the evening feeling less tired. In a little book entitled "Motion Study," Mr. Gilbreth has explained how he worked out his new system. In bricklaying, for instance, he spent some months studying every movement made by a man who was laying bricks, and he laboured at the same work himself and felt how it told on his muscles. Then step by step he thought out a new way of picking up bricks, a new way of laying on mortar, and a new way of stacking material ready for use. He improved the trowel and other tools, and altered practically all the motions made by the bricklayer in picking up and laying a brick. The general result was that his workmen, when thoroughly trained in the new methods, were able to do much more work, earn more money, and keep in good health.

TOWERS THAT REPLACE SCAFFOLDING

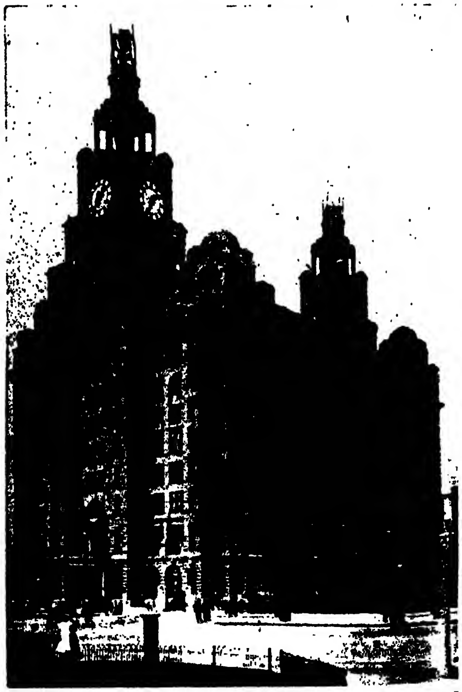


The many-storeyed structures of to-day are built by huge cranes set up on lofty derricks. The cranes lift from the ground all the steel girders, and lower them into their exact positions, where riveters await them. This method does away with the use of much costly scaffolding.



STEEL RODS FOR REINFORCING THE CONCRETE WALLS OF THE ROYAL INSURANCE BUILDING

STEEL RODS AND TEMPORARY WOODWORK READY FOR THE ADDITION OF CONCRETE



THE ROYAL LIVER BUILDING, LIVERPOOL, BUI[illegible] ENTIRELY OF REINFORCED CONCRETE

A BUILDING MOULDED ON THE GROUND

The use of reinforced concrete has enabled builders to complete house-walls in a horizontal position. In these pictures we see a large military mess-hall in course of construction, the bottom picture showing the front seventy-six foot-wall rising into position.

Mr. Gilbreth has applied the same principles of motion-study to his concrete system. The way in which even a wheelbarrow should be loaded and moved has been worked out by motion-study; and of course the design and the making and the handling of the standard wooden moulds have been the subjects of long and minute experiments. The chief aim of scientific management is to economise the muscular force of the workman. He is studied as if he were a machine, and all his movements are standardised and his output exactly measured.

On the whole, scientific management improves the lot of the workman. It is found, for instance, that firms providing recreation-rooms for their men, and baths, fields for sport, and good meals at cost price, obtain by a general increase of working ability a very profitable return for the money spent in making their employees happy.

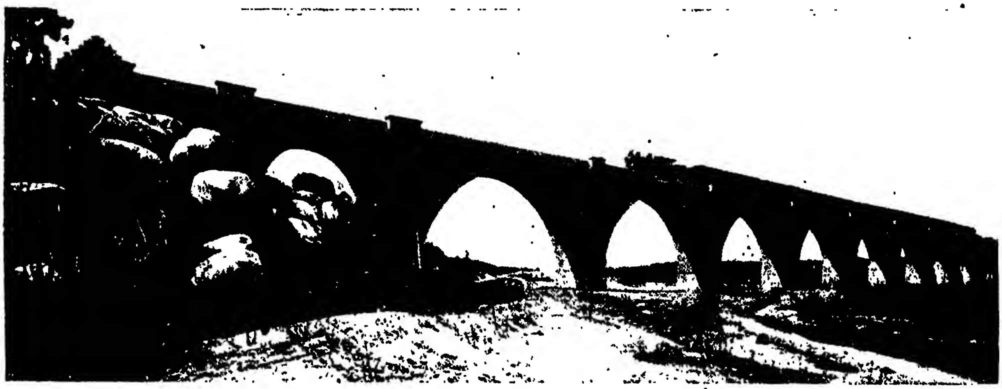
While the Americans have been developing the science of concrete work, the architects of Southern Germany have made splendid progress in the artistic treatment of the new material. Severe and simple in treatment, but exquisite in proportion, their large buildings and small houses have both beauty and character. Erected in a city or town, their white façades, in which the windows are finely placed, ennoble and dignify a street; and when one of these white houses is set in the green country-side, it mingles with the landscape in a picturesque way which delights the eyes of a painter.

In Great Britain there is yet no public architecture of original merit. The best we can do in large buildings is to imitate some historic style, and as a rule we imitate it very badly. The most promising of our architects seem incapable of anything better than copying the work of French and English builders of the seventeenth and eighteenth centuries.

In domestic architecture, on the other hand, our nation has lately become pre-eminent. Here, Mr. Ebenezer Howard, the originator of the Garden City, has finely inspired our younger architects by starting a movement which is already having an effect on our national life. Close to Hampstead, on one of the most expensive sites near London, cottages are now being built and let for 6s. a week, which are not only soundly constructed, but beautifully designed in relation to the other houses in the street. Open gardens on every side give the picturesque and low-roofed dwelling-places the maximum amount of light and air, and pleasant green and flowery spaces add to the loveliness and healthiness of the charming little town. All this is done with a considerable profit to the company which is building the estate; so there seems no reason why the slums should not now disappear entirely from our country.

If concrete work were used, the cost and the rent of the houses would be still further reduced. Merely by employing concrete blocks, Mr. St. Loe Strachey has built a pair of cottages for £150 each. A rent of 3s. a week would be a fair return on this sum. It is true that in the ordinary way such a cottage would cost about £169; but if the latest methods were employed on a fairly large scale, it is possible that a larger house could be built for only £150. For surely the standardised wooden moulds which Mr. Gilbreth uses in large buildings in America could be adapted to the purpose of domestic architecture.

Unhappily, there is still a considerable prejudice against concrete houses in England, though, as a matter of fact, such houses are now made stronger and more



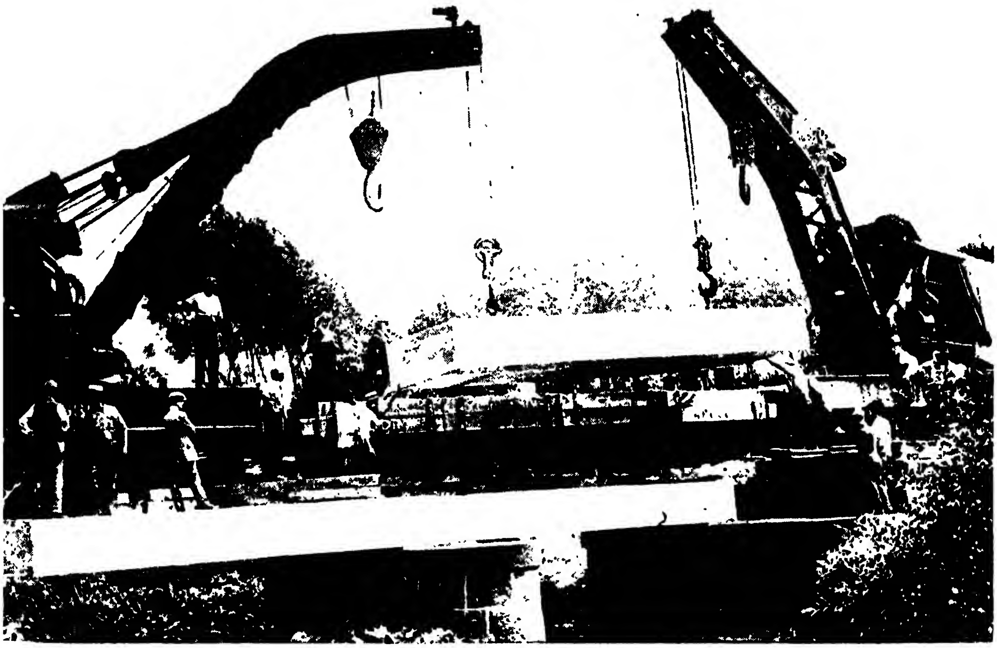
A CONCRETE ARCH-BRIDGE IN CALIFORNIA ONE THOUSAND FEET IN LENGTH

lampproof and fireproof than brick or tone structures. They cost less to build nd less to maintain, owing to the extraordinary durability of the new material. It an be made in various colours, and moulded nto harmonious lines and exquisite forms. What our country now needs is a rich, powerful, and enlightened firm of builders, eady to lay down a considerable sum of noney in standard moulds, in which shall e displayed the best science, the best art, nd the best workmanship of the new era n architecture.

Already in America they are beginning to nake churches and houses in pieces. A

its permanent upright position. When all the walls are in place, the corners from which steel rods project and interlock are "poured," and floors and roof of concrete are cast in the ordinary way. The wooden platform and its machinery can be used over and over again.

From the point of view of health, no building material can be compared with armoured concrete. All hospitals and schools and large buildings should be constructed entirely with it. Especially is it necessary to do away with wooden floors and wooden stairs and all kinds of boarding. This is easily done in a modern concrete



A CONCRETE BRIDGE THAT WAS PLACED INTO POSITION IN A DAY

wooden platform is laid on the ground, and nachinery is placed beneath it, by means of which it can be raised. All door-frames, window-frames, and other openings are set n their proper positions on the platform, and the reinforcement of steel rods is arranged horizontally and vertically. Then he concrete is poured in. In this manner a wall 200 feet long and three storeys high can be cast in a single day. It is allowed o set for forty-eight hours, and then a small engine puts in motion the machinery beneath the platform, and the huge wall rises from the inside, slowly and quietly, to

building, where the floor and wall surfaces can be designed in softly beautiful colours. Concrete is vermin-proof, no rats or mice or insects can burrow into it. Moreover, the fungus growth which spreads in the course of time in old buildings cannot form on the new material, and there are no lodging-places for the microbes of disease. By means of a hose, a building of armoured concrete can be cleaned inside and out with ease and rapidity. Cheap and beautiful, sanitary and everlasting, English concrete is surely destined to revolutionise the habitations of man throughout the world.

This picture, by Erskine Nicol, of the departure of an Irish emigrant family was specially characteristic of Ireland fifty years ago, but now the tide of emigration sweeps over every country in Europe.

MANKIND'S TRADE GROWTH

The Maintenance by Great Britain of her Remarkable Lead in a Rapidly Developing World

HOW WE MAY HOLD OUR SUPREMACY

Europe, the cradle of white civilisation, still maintains a remarkable lead in the world of commerce. In spite of the discovery and development of the mighty American continent, and of the great lands at the Antipodes, and although the Dark Continent has had some little light thrown upon it, and a new sun has arisen in the Far East, the great European nations, headed by the United Kingdom, still do far more trade than all the other four continents put together. Europe still dominates the world. How long will this remain so? Or, to widen and amplify the question, will the white races for ever rule the world? The answer to this question is of deep importance to the world at large, and the considerations which arise are many and far-reaching.

We have already touched upon the question of the maintenance of white leadership in Chapter 9. The most deplorable symptom in this connection, not only in Europe, but in America, is the falling birth-rates of the white peoples. It has gone so far in France that the Census of 1911 has revealed that in the five years 1906-1911 the French population increased by little more than three hundred thousand people, and that in spite of an improved death-rate. In the United Kingdom the birth-rate has also fallen rapidly, and in the third quarter of 1911 it was at the rate of little more than twenty-four per thousand per annum, the lowest rate recorded since British civil registration first began. In Germany also the birth-rate has considerably declined in recent years, although it is still at a higher level than in either France or the United Kingdom.

We do not yet know how far preventive medicine will be able in practice to pull down the death-rate, but obviously there is a limit to its fall. At the Antipodes they have got it down to about nine per thousand, or about five points less than in the British Isles; to reduce it much below nine would probably be difficult. Whatever the limit is, it seems likely to be reached long before the fall in the birth-rate is checked, and in the United Kingdom we are threatened with the same national danger which has already arrived for France—a stagnant or even declining population. No question more demands public attention, either here or in the other white lands, which are mainly the countries of Europe. It is this uncertainty with regard to the future of population which chiefly clouds our vision of the future of the world's development and commerce; and it cannot be too clearly realised that if the facts we are about to review are to remain satisfactory from the standpoint of the leading races of the world, the white nations must awaken before it is too late to the grave lesson which is to be learned from a survey of their vital statistics.

Europe has been for many years feeding the "new" lands of the globe with emigrants. How is that feeding to go on if the European reservoir of population ceases to be filled? If Europe fails to supply surplus population for the colonising of the great unworked areas of North and South America, of Australasia, and of Africa, large areas of the world may yet pass out of the dominion of the white man, with unmeasurable consequences to the New World and the Old.

So far, the process of peopling the outer world, if a European writer may be pardoned for using that expression, has proceeded satisfactorily, with results which we have already partly surveyed. And Europe has sent not only her surplus population, but a share of her capital savings to develop prairie and forest and mine and power-supplies in every latitude. Three European

nations — the United Kingdom, Germany, and France—have each invested over one thousand million pounds sterling mainly in "new" countries. The United Kingdom, it is credibly estimated, has over £3,500,000,000 invested oversea. One half of this is placed in British North America, Australasia, South Africa, India, and other British possessions; the remaining half is almost entirely invested in the Latin-American countries and in the United States. Argentina alone has absorbed fully six hundred millions of British capital, and is adding to this huge sum every year.

Thus we have a picture of Europe setting herself to develop the world. This is not the picture which presents itself to the individual investor who puts his money into a railway at Winnipeg, a waterworks at Buenos Aires, or a municipal undertaking in Australia. The individual investor pursues a purely private and selfish aim, but the results of his pursuit are none the less world-wide in their consequences.

There is little doubt that, between her exports of people and her exports of capital, Europe is building up new lands which in the time to come will outrival and outpace the lands of their creators, and the people of which will look back almost with astonishment to times when Europe was supreme in the councils of the world and in the commerce of men. But again it is necessary to qualify our considerations by remembering the ominous fall in the European birth-rate. If that continues, together with the emigration of the existing European populations, the balance of the world may alter very quickly indeed in the twentieth century.

The progress of European trade, and of that part of Europe in which we are chiefly interested, is shown in the clear statement printed on this page. It relates to almost the whole of Europe, and shows for each country the imports made for home consumption and the exports of native produce, for the years 1890, 1900, and 1910 respectively. Merchandise alone is included in the statement.

We are thus able to compare the progress made in the last decade of the twentieth century with that of the last decade of the nineteenth century, and a glance at the totals will show what a remarkable comparison it is. The aggregate imports of the European nations rose by 370 millions in the ten years ended 1900, but they rose by 699 millions in the next ten years. Turning to exports, we see that they rose by 237 millions in 1890–1900, but they rose by 625 millions in 1900–1910. The twentieth century has hastened to outstrip the by no means inadequate performances of the

EUROPEAN TRADE PROGRESS IN TWENTY YEARS

NATION	IMPORTS—FOR HOME USE			EXPORTS—OF NATIVE PRODUCE		
	1890	1900	1910	1890	1900	1910
	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £
United Kingdom	356·0	459·9	574·5	263·5	291·2	430·4
Germany	208·1	283·5	423·3	166·4	226·7	367·1
France	177·5	187·9	270·4	150·1	164·3	240·2
Holland*	107·6	162·5	(1909) 259·0	90·1	141·0	(1909) 204·0
Belgium	66·9	88·6	150·3	57·5	76·9	114·2
Italy	52·8	68·0	128·2	35·8	53·5	80·3
Austria-Hungary	50·9	70·7	118·5	64·3	80·9	99·7
Russia	41·6	66·1	100·6	70·5	75·6	140·0
Switzerland	40·1	48·3	68·8	29·0	35·4	47·8
Spain	35·9	37·8	39·6	37·3	31·8	37·9
Sweden	20·9	29·2	(say) 35·0	16·9	21·7	(say) 29·0
Denmark	14·9	23·1	(1909) 31·5	10·8	15·7	(1909) 24·7
Turkey	18·9	22·0	(say) 25·0	13·7	14·0	(say) 15·0
Norway	11·2	16·7	(1909) 19·8	6·9	9·0	(1909) 13·0
Roumania	14·5	8·7	(1909) 17·0	11·0	11·2	(1909) 18·0
Finland	?	10·8	(say) 15·0	?	7·9	(say) 10·0
Portugal	10·0	13·4	(1909) 14·6	4·9	6·9	(1909) 7·0
Bulgaria	3·4	1·8	(1909) 6·4	2·8	2·1	(1909) 4·5
Greece	4·8	5·2	(1909) 5·4	3·8	4·1	(1909) 4·0
Servia	?	2·1	(1909) 2·9	?	2·7	(1909) 3·7
Europe .. .. .. (almost complete)	1,236·0	1,606·3	2,305·8	1,035·3	1,272·6	1,897·1

* These Dutch figures, although officially stated to relate to home consumption and national exports, undoubtedly include a large proportion of mere transit trade.

nineteenth. What is true of the European trade totals is true, it will be seen, of every European nation except Turkey and Portugal. Apart from these two countries, the large and small nations alike have made unprecedented progress in the last ten years.

Amongst the most notable increases in imports in 1900-1910, in millions of pounds, were: The United Kingdom, 115; Germany, 140; France, 82; Belgium, 62; Italy, 60; Austria-Hungary, 48; Russia 34; Switzerland, 20.

The corresponding increases in exports are fully as remarkable: The United Kingdom, 139; Germany, 140; France, 76; Belgium, 37; Italy, 27; Austria-Hungary, 19; Russia, 70; Switzerland, 12.

The increases of the minor nations are in some cases proportionately as great, and it is good to see that Spain more than recovered the decline in her exports which occurred in the last ten years of the old century. We have learned not to expect progress from Turkey, and it will be seen that the Balkan States, released from Turkish rule, have made substantial progress; Bulgaria doubled her exports in the last ten years.

It is satisfactory to note by what a considerable lead the United Kingdom still holds first place among the European Powers, and therefore in the world. The British figures were, of course, most difficult of all to maintain or increase, because of their size. In 1911, it may be added, a further increase was recorded, British exports of native produce and manufactures rising to 454 millions. External trade means so much more to us than to any other great industrial Power, for the reasons we examined in Chapter 3, that this fact must give us great satisfaction. The remarkable acceleration of commercial progress in the present century encourages us to entertain legitimately the hope that Great Britain can yet support a much larger population, if her vitality does not decline.

Asian trade progress in the same period can be broadly measured by the statement on this page. It will be seen that the trade of India—British India—stands for a very large proportion of the whole. Indeed, if we put the three British possessions, India, Ceylon, and the Straits Settlements, together, we find by far the greater part of Asian commerce accounted for, and that although the mighty population of China forms so large a part of Asia, and, indeed, of the world. It is a remarkable object-lesson in the achievements of white government. The wonderful mineral wealth of the Straits Settlements, for example, would still be lying largely dormant but for European exploitation. Ceylon has actually a much greater trade than ancient Persia. The Dutch East Indies, because of white management of Asiatic resources, has almost as great a trade as the vast and varied land which Europe knows as China.

The chief thing the Asiatic table shows, then, is that some parts of Asia are being developed, and that others are not. Japan, by adopting the methods of the white man, has already built up as big a commerce as China, although her population is but about one-eighth of that of China. Since 1890, her imports have risen from 13 to 47 millions sterling, and her exports from 9 to over 46 millions; that gives us a hint of Asiatic possibilities. What could not China do with her far greater natural resources if, at last resuming the progress which was so strangely arrested within her many centuries ago, she applied the science and arts of the West in a

TWENTY YEARS OF PROGRESS IN THE TRADE OF ASIA

COUNTRY	IMPORTS			EXPORTS		
	1890	1900	1910	1890	1900	1910
	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £
India	70·4	74·5	121·0	76·8	84·9	149·2
China	32·9	32·8	(1909) 54·3	22·6	24·7	(1909) 44·0
Japan	13·3	30·6	47·3	9·1	21·5	46·5
Straits Settlements	24·5	31·4	42·5	21·3	26·3	37·8
Dutch East Indies	?	14·7	(1908) 20·3	?	19·2	(1908) 37·7
Ceylon	4·7	8·2	10·9	3·8	6·3	11·1
French Indo-China	?	8·0	9.0	?	6·4	8·5
Persia	?	5·6	(1908) 7·1	?	2·9	(1908) 6·3
Philippines	?	4·2	(1909) 5·7	?	4·1	(1908) 6·5
Asia (not complete)	?	210·0	318·1	?	196·3	347·6

nation which fronts the Pacific, and has magnificent opportunities for trade with all the world? It will not fail to be noticed that Chinese progress in the last ten years has shared in the general acceleration. He would be a bold man who attempted to name a limit to that progress in the twentieth century.

The trade of Africa presents some curious features in the table on this page.

The countries, arranged in the order of trading importance, are headed by British South Africa, the commerce of which forms almost one-half of the entire trade of the whole continent. The figures here include bullion, and it is the South African gold-mines which account for her position. The comparative figures in this case are not of much use, since in 1890 British South Africa did not, of course, include the Transvaal and Orange States, while in 1900 the country was devastated by war.

What is one of the most remarkable instances in the world of the results of white leadership is exhibited in the Egyptian figures. In the twenty years since 1890, Egyptian imports rose, in pounds sterling, from eight millions to twenty-four millions; while Egyptian exports rose from twelve to nearly thirty millions. Thus, under British rule, the commerce of Egypt nearly trebled in two decades. It is a remarkable tribute to what happens when the white man takes up his burden. Egypt had the fructifying Nile no less in 1890 than in 1910; and there is not the slightest doubt that, without European guidance, the Egyptian figures of 1910 would have been but little greater than those of 1890, or even 1880.

Tribute must also be paid to the effective work of the French in Algeria and Tunis. We cannot in these cases trace progress during the whole of the period we are considering, but the last ten years have witnessed substantial and promising advances. With better government in Morocco and in Tripoli, it is beyond doubt that the whole of the North African continent, from east to west, from Egypt to the Atlantic, will in the twentieth century recover more than its ancient importance, when Carthage dared to war with Rome, and when Cyrenaica was a granary for the rulers of the world. The desert, which in many parts has been for centuries steadily marching to the sea and crushing the races who knew not how to fight it, as it was fought by the Carthagenian, by the ancient Egyptian, and by the Romans, will be compelled once more to retreat, and a part of man's inheritance will be re-won from Nature.

In tropical Africa a start has been made in the subjugation of Nature in her fiercest moods. We see British West Africa with a commerce actually worth twenty millions a year, which is more than Egypt possessed as lately as 1890. Here man takes up his heaviest task of development, and it is impossible to hazard more than a guess as to how the trade statistics may grow. Everything depends upon whether white men will ever find it possible, as we now dare hope, to colonise the tropics.

We must pass from lands which Cæsar knew to those great territories which Cæsar never dreamed of. We come to what are in the main White Man's lands in the Americas.

The statement of American trade progress which follows on the next page is easily the most wonderful of the series we are considering.

TWENTY YEARS OF PROGRESS IN THE TRADE OF AFRICA

COUNTRY	IMPORTS			EXPORTS		
	1890	1900	1910	1890	1900	1910
	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £
British South Africa	14·6	26·4	40·1	11·4	9·3	55·4
Egypt	8·3	14·5	24·2	12·2	17·6	20·7
Algeria	—	13·6	20·5	—	9·7	15·7
British West Africa	—	4·1	11·0	(say) 1·0	3·5	6·8
Tunis	—	2·5	5·0	—	1·7	4·0
Senegal	—	1·4	2·8	—	1·2	2·5
Mauritius	2·0	2·1	2·5	2·8	2·1	2·5
British Guiana	1·9	1·3	1·7	2·5	2·0	1·7
Madagascar	—	1·6	1·4	—	0·4	1·3
British East Africa Protectorate	—	0·4	1·0	—	0·1	1·0
Africa (not complete)	27·4	67·9	110·2	29·9	47·6	125·0

We have already noted how great an amount of capital has been furnished by the United Kingdom for the development of American resources. An enormous sum, nearly £700,000,000, has been sunk in United States enterprise by British investors, and every year we draw a big tribute of imports in payment of the interest. The commerce of the United States has naturally grown with her vast agricultural, pastoral, mineral, and industrial developments, but it is still chiefly food and raw materials which America sends over the seas. Reference to the European facts will show that in 1910 the exports of the United States rose above those of Germany, and thus came to be second to those of the United Kingdom. The character of her exports is entirely different from that of the German outward shipments, however, and the United States is not yet in the same rank as Britain or Germany in the export market. What she sells abroad consists chiefly of raw products which sell themselves, and which the world must have.

This may not seem very flattering to American commerce, but it is a plain statement of the facts of the case. As a matter of fact, the United States exports of manufactures are still well below £200,000,000 sterling per annum. The precise figure for the twelve months ended June, 1911, was £180,000,000, or considerably less than one half the total exports in the same period. We must, however, expect to see this figure greatly increased; and at some time or other America must take her natural place as a great supplier of manufactured articles to regions less fitted than she is for industrial operations.

Canada, a British Dominion, and Argentina, a foreign country, one in the North American continent and the other in the South, are running neck and neck in the table of American commerce. Canada has the larger imports; Argentina has the larger exports. The figures of both exhibit a most rapid progress; and it is almost incredible that so great an advance has been made by these two nations in the short space of twenty years. The imports of Canada and the exports of Argentina have each quadrupled in that time. Brazil has also done well, and the trades of Cuba, Chili, and Mexico are each progressing very favourably. Uruguay and Peru have no small natural advantages; and we need not be surprised if they have beaten the British West Indies and Newfoundland, which have comparatively small natural resources.

The American continent as a whole—the aggregate of the table covers nearly all its countries—is seen to have an aggregate external trade of enormous dimensions, ranking next after Europe. It is a matter of almost infinite speculation to contrast the European with the American facts, to note the surpassing of ancient European nations by the *nouveaux riches* of North and South America, and to wonder what further changes may not take place in the not remote future. We see Spain, which in 1492 sent Columbus on his fearful voyage into the unknown, beaten hollow in commerce by no less than four American nations, and well on the way to be beaten by several others. We see Turkey, against whom Venice and Austria warred centuries ago for the salvation of Europe, insignificant in trade statistics; and Italy, which gave Columbus and Cabot to the world, being

TWENTY YEARS OF PROGRESS IN THE TRADE OF AMERICA

COUNTRY	IMPORTS—FOR HOME USE			EXPORTS—NATIVE PRODUCE		
	1890	1900	1910	1890	1900	1910
	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £
United States	161·8	173·0	325·6	176·1	285·6	380·7
Canada	25·0	37·3	94·7	19·5	37·6	59·6
Argentina	28·5	22·7	(1909) 60·6	20·2	30·9	(1909) 79·5
Brazil	(?) 18·0	(about) 21·0	(1909) 37·1	(?) 25·0	(about) 40·0	(1909) 63·5
Cuba	(?) 12·0	14·8	(about) 20·0	(?) 8·0	9·3	(about) 20·0
Chili..	14·1	9·6	(1909) 19·7	14·2	12·6	(1909) 22·3
Mexico	10·8	12·3	(1909) 16·0	13·0	14·9	(1909) 23·6
British West Indies ..	6·4	6·5	8·6	6·0	6·2	8·0
Uruguay	6·7	5·0	(about) 7·5	6·0	6·1	(1909) 9·4
Peru	(?) 2·0	2·3	(about) 5·5	(?) 4·0	4·5	(about) 5·5
Newfoundland	1·3	1·5	2·6	1·3	1·8	2·4
America .. .. .. (chief countries)	286·6	306·0	597·9	293·3	449·5	674·7

rapidly overhauled in trade by Canada, Argentina, and Brazil.

To those who pray for the maintenance and safety of white leadership, the rapid progress of the great and little Americas is a thing most welcome. The American continent lies athwart the world; and when the Panama Canal is opened about 1915 the American peoples will have a tremendous strategical position. With the Americas bound together in some sort of loose confraternity, and linked possibly with a friendly federation of European States, the rule of the white man should be secure, unless, as we have said, the white man commits the criminal folly of race suicide.

AUSTRALASIAN TRADE PROGRESS IN TWENTY YEARS

COUNTRY	IMPORTS—FOR HOME USE			EXPORTS—NATIVE PRODUCE		
	1890	1900	1910	1890	1900	1910
	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £
Australia..	?	41·4	60·0	?	46·0	74·5
New Zealand	6·2	10·6	17·1	11·8	13·2	22·2
Australasia (chief parts)	?	52·0	77·1	?	59·2	96·7

And in the solution of the great problems of the Pacific, we must hope that Australasia will play a not unworthy part. The commerce of Australia and New Zealand is shown in the accompanying statement, and it exhibits the most promising development. Owing to the federation of the Australian States, we cannot give comparative figures for the twenty years, but those of 1900–1910 are exceedingly good, and well worthy to rank with those of the Americas. New Zealand, with her one million people, is also flourishing, and we see that she has trebled her imports and doubled her exports in twenty years. Her lovely islands will, we hope, some day be the home of tens of millions of white people.

It is of deep interest to the British reader to add a separate statement of British Colonial trade progress, and this is done in the statement on the next page, the figures covering both merchandise and bullion. It is not possible to give a satisfactory twenty years' comparison, but progress in the last ten years has been exceedingly good, and if it out-distances that possible to an old and developed country like the United Kingdom, the citizen at the heart of the Empire will not begrudge the fact. The aggregate imports of the various Dominions and Colonies are seen to amount to £426,000,000, and the exports to £444,000,000. If advance continues at the rate of the last ten years, we may easily see these figures doubled in the next decade or so.

The existence of great and flourishing "new" countries which are hungry buyers of the manufactures which the United Kingdom chiefly has to sell ought not to blind us to the latent possibilities either of the home market or of the European markets close to our shores.

The British trader has often been blamed by our consuls and commercial agents for lack of "pushfulness" in various parts of the world. Discount has always to be made from these criticisms, because it is only human for a British consul to think that his own country ought to have all the trade, and to be therefore disappointed when a contract goes to Germany or Belgium. Moreover, it is also exceedingly human to magnify one's neighbours possessions at the expense of one's own. As Horace puts it: "Always fertile are the fields of our neighbour." If, however, reproach justly lies against the British exporter, it is certainly in the rich markets of Europe, which, as will be gathered from our survey of the world's trade, are still the finest in the world. When we examine in detail the comparative progress of the United Kingdom and Germany in the export market, we are struck with the fact that it is in Europe that Germany has made some of her largest gains, and that it is in Europe that we have been least successful in recent years.

If we take the last fifteen years, we find that the United Kingdom has gained very little in the European market, whereas Germany has about doubled her exports to the nations round her. This is partly due to superior pushfulness, partly to the extraordinary advantages given to Germany by her national railway system, and partly again to her production of specialist

manufactures. The German is a Continental, while the Briton is inherently insular. The German is familiar with Continental cities and markets, while the Briton is often supremely ignorant of Continental customs or requirements. There is not the slightest reason why the British exporter should thus handicap himself. It is but a short journey to any of the European markets, and there is no reason in the world why the British commercial traveller should not be as familiar as the German in Vienna or Milan or Berne. Insularity is excellent as a means of defence; it is unfortunate as an accompaniment to commerce.

With regard to the nature of articles suitable for Continental trade, it would undoubtedly be well for us to call more largely to our aid science in production and art in design. In quite a number of trades science and art play almost equal parts. The extraordinary degree of perfection to which the Germans have attained in the chemical manufacture, in musical instrument making, in glass manufacturing, and in metal working, to name but a few examples, illustrate this point.

When we have combined the commercial qualities, the scientific qualities, and the artistic qualities, we have still a formidable exponent of industry and trade; and we can understand why Germany is able to enlarge her exports in markets round her which demand artistry in many branches of manufacture.

The general conclusion is that while we have every reason to be gratified with the excellent place which we have secured and which we still hold in the world's markets, we have to remember very carefully that the trade competition of the future will not only be increasingly strenuous, but concerned with an ever-rising quality as well as quantity of production. The days of rule-of-thumb output are passing for ever, and the trained expert will universally rule the industry and commerce of the future. It follows that, in holding our own at the head of a great Empire, we have very seriously to seek a better training for our industrial and commercial *personnel*, and to understand that this is as indispensable for the private as for the captain of industry. It is necessary to say this because there have not been wanting in recent years some signs that in matters of modern attainment we are not quite holding our own. A most striking illustration of this is to be found in aviation, in which Britain, as an island, ought to be supremely interested, for the conquest of the air means the loss of insular protection. In spite of this obvious fact we know that three or four Continental nations are far ahead of us in both the science and the art of aerial navigation, and that the best engine for aeroplanes is of French manufacture, which is a curious reproach to the land which produced James Watt and George Stephenson. Given an educated people led by scientific captains of industry, and the British people may easily rise to much higher levels of attainment in the industry and commerce upon which their very nationhood depends.

BRITISH COLONIAL TRADE PROGRESS IN TEN YEARS

The figures here cover both merchandise and bullion

DOMINION OR COLONY	IMPORTS—FOR HOME USE			EXPORTS—NATIVE PRODUCE		
	1900	1905	1910	1900	1905	1910
	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £	Mill. £
India	74·5	101·3	121·0	84·9	122·6	149·2
Canada	39·0	54·8	96·8	39·4	41·8	61·1
Australia..	41·4	38·3	60·0	46·0	56·8	74·5
Straits Settlements	31·4	33·2	42·5	26·3	28·4	37·8
British South Africa	26·4	35·0	40·1	9·3	35·8	55·4
New Zealand	10·6	12·8	17·1	13·2	15·7	22·2
British West Africa	4·1	5·5	11·0	3·5	5·3	9·8
Ceylon	8·2	7·7	10·9	6·3	6·8	11·1
British West Indies	6·7	7·6	8·9	6·4	7·1	8·3
Total above and other Colonies..	252·8	309·0	426·0	245·6	332·6	444·5
Trade done with:						
(a) United Kingdom	118·3	143·2	183·9	108·8	144·1	198·0
(b) British Possessions ..	48·8	58·2	64·9	45·3	57·7	60·5
(c) Foreign Countries	85·7	107·6	177·2	91·5	130·8	186·0

A MAN WHO CONQUERED AN EMPIRE BUT WON NO RENOWN

The story of the Spanish conquest of Peru is a record of greed and cruelty that has few parallels in history. Pizarro, the conqueror, was a man who could neither read nor write, and, though he was full of courage and daring, his success was due to treachery rather than to bravery. At a friendly interview he suddenly seized the Inca, or ruler, as shown here, and, after extorting a huge ransom for his life, killed him.

UTOPIAS OF THE REDSKINS

Utter Savagery Side by Side with Imperialist Socialism Among the Red Indians

SOME PROBLEMS OF SOCIAL EVOLUTION

There are few persons who have never felt, at some time or other, the romance of history. Perplexed by the problems of daily existence, dulled by the routine of our work, we look back with longing to the ages when human society was less rigidly organised, and life was more adventurous and more picturesque. Our poets, painters, and novelists charm us with visions of the clash and colour of the feudal era. Some even go back in fancy to the wilder days of the ancient Britons; and lately we have had from Mr. H. G. Wells and Mr. Rudyard Kipling strange stories of life in Britain in the rude Stone Ages.

A curious error, however, underlies nearly all these historic and prehistoric romances. It is generally assumed that the kind of life depicted has long since passed away, and that nothing now remains but the somewhat colourless industrial civilisation which we are all helping to build up and improve. But, as a matter of fact, practically every form of human society that men have ever fashioned can still be found existing on this earth. Our world at the present day is wonderfully interesting, and full of wild, fantastic contrasts. We can travel up the river of time as easily as we can journey across space. Return tickets to the Stone Ages are sold at all our great seaports. Trips to the barbaric and feudal eras are as common as excursions to Brighton were sixty years ago. "Weekly from Southampton, the great steamers, white and gold, go rolling down to Rio," as Mr. Kipling sings. And north of Rio, on the east coast of Brazil, there is a race of Indians who have not yet emerged into the Old Stone Age.

They are known as the Botocudos. Like all so-called Redskins of America, they are really a race of yellow-skinned people; and, through living in the tropical forest, with its leagues of shadowed stillness, they retain a peculiar yellowness of complexion untouched by any sun-tan. Dwarfed in body, with beetling brows and sunken noses, they wander in a state of absolute nakedness on the wooded heights three hundred miles north of Rio Janeiro. They have only wooden weapons, and bags of vegetable fibre, and they possess no knowledge of the art of navigation. Lower in culture than the men inhabiting Europe two or three hundred thousand years ago, they do not know how to get a cutting instrument by chipping the edge of a stone, and they use merely bamboo knives and bamboo arrow-heads. Their dwellings are branches of trees stuck in the ground, loosely tied together with strips of bark, and seldom made more than four feet high Yet two or more families may often be found crouching under one of these structures.

Roots and berries, honey, frogs, and snakes are collected by the Botocudos, and form their principal food. With their feeble weapons of wood and their extremely low social organisation these savages are scarcely more advanced than was primitive man when he leapt down from the trees and began to contend with the larger beasts of prey for the lordship of the earth. In one respect, indeed, the Botocudos are the most degraded of human races that ever existed. Lacking the power of mind and the ability for social combination which enabled the great hunting peoples to master every animal, these vile and cowardly Indians prey on their fellow-men. They eat their own relations. Even the pre-human unit of society, the family, does not maintain itself among them. The union of the sexes is temporary, and the women are treated with extraordinary cruelty.

There is no government save when some

wizard manages to get control of several families, and acquires a sort of chieftainship. When he dies or grows weak with age, the families split up and continue their scattered life.

Compared with the communities of ants, whose little cities are the plague of the Brazilian settler, the Botocudos can scarcely be said to be social creatures. There is in Brazil a certain kind of ant so numerous, so ravaging, and so invincible that, in the absence of gunpowder and other modern means of destruction, civilised man would be compelled to retreat from its territories. Even at the present day it often costs more to destroy the anthills than the land is worth. Were mankind generally still at the level of the Botocudos, both northern and southern America would eventually become the dominion of the ant. The insect, by reason of its almost perfect social organisation, would triumph over humanity.

Perhaps we shall not go far wrong in attributing the degraded social condition of the Botocudos to a sluggishness of mind mainly induced by the natural fertility of their tropical forests. Food of a sort has always been abundant, and there has been no incessant stimulus to invention.

The Low Forms of Human Existence that Remain where Life Needs no Effort

Many of the native tribes of the tropical regions of South America are—or have been—fierce, low, wandering savages, with no knowledge of agriculture and hardly any social organisation. A somewhat similar state of things may be observed in the forests of Central Africa, where also the means of life have been for hundreds of thousands of years too easily purchased. In Central Africa, however, invasions and migrations of peoples and mixtures of races have now somewhat obscured the various lines of stagnation and development. In America these lines can still clearly be traced.

Bordering on the territory of the slothful savages of the tropical forests, there is a race of Red Indians, speaking the Quechua tongue, whose lot is cast in a hard, rigorous climate. They live on the highlands of the Andes. They are scarcely taller than the Botocudos, but their heads are perhaps somewhat more massive. Dwelling in a temperate climate, two miles above the sea-level, the mountaineers have been hard put to it to earn a living. Much of their land is too cold to bear any crop, and it was as shepherds that they entered on the path leading to civilisation. They caught and tamed the llama, and then went on to till the lower, warmer slopes of their snow-clad heights. The arts of metal-working were discovered, and the crafts of building reached a perfection which has been equalled, in its special way, by no other nation in the whole world. The pottery of the mountaineers is also remarkably fine, and their feats of engineering are considerable.

Setting out with the fund of superstitions common to all the American native races, they arrived at the idea of a Divine Father, and then put their belief in the brotherhood of man into practice with an energy, a thoroughness, and a genius for organisation to which no other human society can offer a parallel.

The High Type of Organised Government Created by American Mountain Tribes

On a space of two thousand miles along the western coast of South America there lived at last ten million people, each of whom had a fair amount of food and work apportioned to him by the State. Everything was provided by the central Government—provisions, medicine, land, the exchange of commodities, irrigation works, splendid roads, magnificent cities, and help of every kind. All that was asked of the ordinary citizen was that he should do his fair share of work. An overseer was set over every ten families; a headman over every ten overseers; a chief over every ten headmen; and a lord over every ten chiefs. All the lords were ruled by an emperor.

This Socialistic form of government produced a wonderful contentment among the people, and the entire machinery of the society worked with incomparable smoothness. The people were warlike, and they constantly extended their boundaries by conquest. The subject races, however, were treated as equals, and allowed all the privileges of citizens, and their condition was so happy that they remained well content with their defeat and absorption.

The Treacherous Destruction of South American Socialism by Pizarro

The Empire of Socialism thus founded on one of the bleakest spots of South America was, as is generally known, destroyed by a small troop of Spanish adventurers under Pizarro. It was accomplished by inviting the Indian Emperor to a conference, and capturing him and holding him as a hostage, and then murdering him—a foul, mean act of treachery worthy of the Botocudos.

Yet the Socialistic State founded by the mountaineers, and continued by the Incas of Peru, is not wholly a thing of the past,

even now. Three centuries of horrible massacres and tortures reduced the number of Quechua peoples from ten millions to a million and a quarter, and the last known Inca was murdered by the Spaniards, with the usual treachery, in 1783. But though the names of the present native rulers of the Indians of Peru are not known to the outside world, the descendants of the ancient Emperors still live and rule over two million people on the uplands of the Andes. They meet, it is said, in secret congress, and discuss all matters relating to the welfare of their people. The marvellous force with which the civilisers of the New World have faced adverse circumstances, which would have swept most races from the earth, gives ground for the hope that under a more humane rule and a juster government they may again multiply and resume their high place on the earth.

The Wide Range of Society as Constituted in the Most Primitive Ages

In any case, their social achievements must ever rank among the finest attempts at the organisation of humanity. We cannot say that the ant looked like conquering them. Their government was, indeed, the nearest approach made in a vast, continuous, and practical way to excel the wonderful insect communities in their own form of social arrangement.

We have contrasted at length the Botocudos and the Quechua peoples, because these are vividly representative of the two extremes of early social organisation. Between the utterly Anarchic group and the rigid Socialistic community, there is a multitude of human societies of various kinds scattered about the world. There are clans in the Old Stone Age, and tribes in the New Stone Age; loose confederations which have only recently discovered the use of copper; farming races who use iron in a rough and primitive way; and warlike nations inspired by a fierce, picturesque chivalry and still swinging between the barbarism of our Dark Ages and the despotic captaincy of some strong-handed leader.

The Rise of the Power of the Priest in the Earliest Ages

Some lands are ruled by a strange and mystic priesthood, like that of ancient Egypt; and not far away from the pagan theocracy is still found its lowly source in the witch-doctors that bear sway over some low, savage, unwarlike tribe. Sometimes we can catch the witch-doctors in the process of developing into a heathen priesthood with little or no political power, being kept in check by a warlike chief who is growing into a monarch. Sometimes the chief himself has certain priestly functions, and we can then trace the old idea of the divine right of a king back to the superstition of an ancestral god from whom the chief is supposed to be directly descended. It is very curious to reflect that the divine right of a king, on which even so modern-minded and enlightened a ruler as the present German Emperor sometimes insists, has nothing behind it, in a historic view, except the primitive dread of ghosts.

The strangest of all existing communities is found among a race of curiously ape-like men who inhabit the remote inland forests of the East Indian Archipelago and part of Malaysia. It was in Java that the remains of *Pithecanthropus erectus*, the ape-like man, were discovered in 1891, and in this tropical region the aborigines retain some of the physical characteristics of the Pithecanthropus. Their enormously projecting jaws, for instance, are more like a monkey's than a man's, and it is just possible that there may be a strain of the Pithecanthropus in them. They are of very small stature, with black skins and woolly hair, and they live naked in the trees. There are unexplored regions where no head-hunting Dyak or Malay will venture, for fear of the tree-people.

The Tree-Dwelling People whose Habits most nearly Approach those of the Higher Ape

From tree to tree, where the branches do not meet and form a bridge, are tied ropes of rattan, and along these aerial forest-ways creep in silence the most primitive race on earth, armed with blowpipes. Tipped with a poison for which no antidote is known, their little arrows are showered down upon any intruder. Of the wildest of these wild tribes, therefore, nothing whatever is known, and only two white men are reported to have seen them —one, an orchid-hunter escaped with the loss of his men; and the other, a mining explorer, caught a glimpse of them just in time, frightened them by firing his gun, and then ran for his life. There are many travellers' tales of the tree-people, but we are informed that they have only been picked up from Dyaks and Malays.

They are now extinct in Java, their primæval home, where the last-known survivor, Ardi, was employed a few years ago in the Buitenzorg Botanical Gardens. Ardi is the most ape-like normal living man of

whom we have full details and photographs. His race, however, lives on, under various names, in other large islands of the archipelago, and in the inland forests of the Malay Peninsula. The Samangs of the central Malay forest are the best known. They are true nomads, without permanent homes, and they camp under frail lean-to's of palm-leaves, wherever game is plentiful. Where, however, they are menaced by other races, they return to the tree-tops, building shelters like the larger monkeys, and living in the foliage. Their skill in rope-walking is extraordinary; and their women have been seen passing from tree to tree, carrying cooking-pots and other effects, with a babe at the breast and small children clinging to their heels.

The Tasmanian Natives and the Light they Might have Thrown on Problems of Early Man

All that is clearly known of this strange race is that the ties of family love are strong, and that the women are respected by the men. They worship a female deity, who is represented under the form of a mysterious warrior queen, haunting the deep recesses of the forest. Armed with her wonderful blowpipe, she will come forth at last, and destroy all the enemies of her people.

Allied by descent to this strangely primitive race were the natives of Tasmania, the last of whom perished in 1877. From what scanty superficial information we have, it appears that the Tasmanians lived only in family groups, with no political organisation. There were certainly no chiefs or anyone who could make any agreements binding on even a small group of families. We can only suspect that there were marriage divisions in the various Tasmanian "mobs"—to use the name the English settlers gave to a loose horde speaking the same dialect. The weapons of the Tasmanians were the crudest Old Stone Age implements, similar to those occurring in the oldest river-beds of England, and their shelters consisted of a single screen of leafy boughs placed to windward. They made fire by rubbing a wooden stick in a groove of harder wood.

The Short-Sighted Destruction which an Unintelligent Civilisation Permits

They went naked, covering their bodies with grease to protect themselves from the wet. Five was the highest number for which they had any word. Some tribes only had three terms for reckoning: these were *mery*, *calabawa*, and *cardia*, which stand for "one," "two" and "plenty," or, rather, anything over two. Their means of navigation was a raft, formed of three rolls of bark bound together with wisps of grass.

There can be little doubt that in these frail and primitive structures the Tasmanians sailed from Java, by Bali, Timor, and other islands, to Australia, and, after colonising Australia, they voyaged across to Tasmania. It is also very possible that the race to which they belonged worked its way from Asia to Europe, inhabiting Britain in the days before the English Channel existed. That means that we have ruthlessly wiped out in Tasmania a harmless race that first received us kindly, and that could have thrown a flood of light on the strange and wonderful history of mankind. As Professor W. J. Sollas, of Oxford, recently remarked:

"If any other nation than our own had shown the same disregard for a human document of such priceless value, we should be very outspoken in our censure. Even now, in this twentieth century, it cannot be said that the British Government takes such an intelligent interest in the numerous primitive peoples which it has taken into its charge as we have a right to expect from a State having regard for the advancement of learning."

The Extraordinary Significance of Paternal Aunts in Savage South Sea Society

As matters now stand, we are unable to trace with any certainty the evolution of the structure of human society. There are many theories on the matter, but facts of primitive origin are hard to get at; and when they now survive, they are mixed up with elements of later cultures. The Tasmanians would have been invaluable, and their extermination reduces us to guesswork. About two years ago, however, a clue was accidentally discovered among some of the islanders of the South Seas. Europeans had been living for about a century with the natives, whose social organisation was reckoned to be well-known. In 1910, however, an aboriginal was asked who was the most important of his relations. He answered, "My father's sister." Thus, neither his mother nor his father was accounted the most important person in his life; and it now appears that the paternal aunt is a figure of extraordinary significance in societies which have retained their primitive structure.

The primitive tribe is divided into two divisions, and descent is always traced from the female side. This is the state of mother-right, the existence of which has led some men of science to the belief that

LOWLY REMNANTS OF AN ANCIENT RACE

INDIANS OF THE ANDES, ECUADOR

MOKI INDIANS OF ARIZONA

DESCENDANTS OF THE INCAS, WHO WERE A HIGHLY CIVILISED PEOPLE FOUR HUNDRED YEARS AGO

woman was once the queen of society. It now appears, however, that the tribal division, and the apparent disregard of the connection between a father and his children, are evidence of an extraordinary male tyranny. The whole thing is merely a marriage arrangement, by means of which the old men get all the young wives, while the young men have to be content with an elderly female clan-relative of their father. The cunning scheme seems to be an early development of the pre-human group, where the jealous sire had several wives, and drove his sons out of the family when they grew up.

The Elaborate Convention of Totemism, and its Effect on Social Organisation

Primitive man used, instead of brute force, the more powerful instrument of convention and custom; keeping the youngest women for himself, he married his sons to the old women of some neighbouring family group with which he had become connected. Such, at least, seems to be the social structure which the Tasmanians maintained for many ages; and vestiges of it can still be found among the savage communities of Australia and elsewhere, in which there subsists a Tasmanian element.

The next stage in the evolution of social structure is found among the black South Sea tribes who succeeded to the Tasmanians. They introduced totemism and clan organisation, magic and descent through the father. Totemism consists in naming a clan after some animal which the clan only eats at a great religious festival, after performing magic rites which are supposed to make the animal flourish in great numbers. The other clans profit by this care and abstinence from the totem; and each of them in turn watches religiously over the welfare of some other animal, which it also does not eat except at its solemn festivals. Such seems to be the idea of primitive totemism, though the matter becomes complicated when clans take their names from natural objects that have little or nothing to do with the food-supply of the tribe.

The Early and Widespread Establishment of Ordeal-Barred Secret Societies

Undoubtedly, totem rites make for social organisation; and we find in many parts of the South Seas that chieftainship has been evolved, together with a curious magico-religious system of taboos which gives the leaders a strong command over the people. Sometimes social life proceeds on the communal plan, large groups living together in big clubhouses. A curious feature of this stage of society is the widespread secret societies. From them, as from the lodges of European Freemasons, women and the uninitiated are excluded. The ghosts of the dead are supposed to be present, and they are consulted by various magical rites. The chiefs are connected with the great lodges, and often use them for political and personal purposes; and there are numerous minor societies which may be started by anybody.

In the more important societies the initiation is a stern ordeal, the candidates being subjected to severe trials of endurance by torture and hunger that sometimes last for weeks. Mysterious and impressive dances, performed in the moonlight, are a chief part of the function of these primitive Freemasons, who band together for mutual help, and often act as a kind of secret police—like the Freemasons of modern France. These secret societies seem to have originated in a conflict between the very low savage races and the higher hunting-tribes.

The Organising Power of the North American Indians Greater than has been Supposed

In some parts of the world the women also form themselves into secret societies, and ill-treat, and even kill, any man caught spying on their mysteries. Probably the Greek legends of the Bacchantes slaying men who broke in upon their gatherings are a tradition of the European secret societies of the New Stone Age. At the present time primitive secret societies chiefly obtain in the South Seas and among the negroes of Africa.

In America the totem organisation of clans and the communal life in large clubhouses were finely developed. Moreover, the American Indian long since developed into a good farmer in many parts of his continent where Nature was neither too harsh nor too kind. So it was probably by retaining the communal structure, while developing the arts of agriculture, that the most advanced Red Indian tribes grew into Socialistic civilisations. It is popularly supposed that the Iroquois and Algonquian tribes of the United States were predatory nomads living entirely by the chase and the scalping-knife. Some tribes were, no doubt, driven back to the hunting stage by pressure from the white settlers, but for the most part they were originally an agricultural race.

Several nations of North America even had an urban civilisation, with actual

towns under municipal government. Scattered over the Mississippi basin and thickly crowded in the Ohio Valley are great earthworks, once supposed to have been erected by a civilised people who were destroyed by the wild Indians long before the coming of the white settlers. It has, however, now clearly been proved that the mysterious mound-builders were well-known Algonquian tribes. They laid their towns out in public squares, with separate buildings for the councillors, the warrior chiefs, and the inferior chiefs, together with a hall for general religious and social purposes. A public bathhouse and a public dancing-yard were found in every central square, and something like a Parliamentary organisation was in process of being evolved. Some wild tribes round the Rocky Mountains still disturbed the peace; but if America had not been discovered until the age of the steamship, the Iroquois, who gave their women a considerable share of political power, would have now established a vast empire between the Atlantic and the Mississippi. In New Mexico and Arizona the Pueblo Indians, pressed by the wild tribes of the north, built huge stone fortresses, sheltering the whole community. Still farther south were the highly civilised Mayas, who were conquered by the barbaric and cruel Aztecs.

Thus we see that the wonderful system of State Socialism built up by the mountain race and the Incas of the Peruvian highlands was not a miracle of the Red Indian mind. In the north, in the centre, and in the south of the New World the Redskin was marching along the path to civilisation, with no help whatever from Asiatic and European culture. In some places he had already reached a solution of the terrible social problems which still perplex us, and in other regions he was well on the way to a system of Imperial Communism developed out of the communal life of the higher savage stage of culture.

REMAINS OF ROCK-PALACES OF EARLY INDIAN TRIBES TO BE SEEN IN CALIFORNIA
This picture reproduces part of an Indian centre of civilisation dating long before the advent of the white man in the Western World. The palaces are built in a sheltered hollow under the protection of a steep and overhanging cliff.

In the Old World the evolution of society was less simple and more varied. Nothing so suddenly perfect as the Inca and Maya civilisations was attained, but social elements and social forces which had been overlooked by the wonderful Redskins were discovered and developed by the slower and more comprehensive races of the Old World. Instead of settling down in happy contentment, they struggled on to that idea of a larger progress which they have not yet worked out.

THE EDUCATION THAT BRINGS TO THE CHILD HEALTH AND PLEASURE WITH KNOWLEDGE

THE GARDEN AT THE OPEN-AIR SCHOOL FOR WEAKLY CHILDREN AT WHITLEY WOOD SHEFFIELD WHERE EACH CHILD HAS ITS OWN PLOT OF GARDEN

DISCOVERY OF THE CHILD

Education the Provision of an Environment in Which the Child can Become its Best Self

EDUCATION NOT LEARNING, BUT BECOMING

In our study of Nurture we have reached the school-age, and first of all found it necessary to consider the school-child from the standpoint of physical health. If we are really to have education of the mind and the emotions and the character, and if the problem of such education is to be solved, or even understood, we must be allowed to begin with healthy children.

It is a difficult enough question for the psychologist and the educator to solve, as to the exact importance and value and relative service of the eye and the ear in education, but plainly, at the very least, they are entitled to assume that the eyes can see the blackboard and that the ears are not thrown out of action by adenoids or the *sequelæ* of measles or scarlet fever.

It having been found that physical health cannot be assumed among the nation's school-children, that disease is rife, and that it is, also, fortunately controllable, almost wholly, by prevention and cure, we have necessarily devoted a chapter to the question of the physical nurture and protection of the national life at the school-age, which will form an integral part of the nation's policy from the present time until the nation and its policies are no more.

We now pass to the problem of education of the higher and distinctively human part of the children, ingenuously assuming that their throats, noses, teeth, and other structures, which they share with swine and fish and fowl, are as well attended to as if the children were really some valuable item in the live-stock of the nation.

Children are individuals, and will develop into individual citizens. The idea of education *en masse* is, therefore, something like an absurdity. But national education must be on a large scale, must possess some measure of uniformity, and cannot be permitted to cost what the nature of the problem demands, until, some day, we discover in what the wealth of a nation really consists. Therefore, some kind of compromise is necessary, between the educational ideal, looked at from the standpoint of science, and the practical necessity, which would prefer to assume that the nation's children are like so much bullion, and that the problem of education is simply the problem of the machinery and the mechanics at the Royal Mint.

If children were worth no more than gold, they might be usefully amenable to the processes which suffice for that or other forms of matter, of which the characteristic is that gold (or lead) is gold everywhere—at all times—producing the same coins from the same dies. But all children are unique.

Let us, then, first discuss, sufficiently for our present purpose, the problem as science sees it, which means the problem of an individual child; then we must look at our system of national education, which has grown up more especially from the year 1870; and finally we shall indicate the various points and lines along which the rigid shell of the bureaucratic system shows signs of bursting, more especially north of the Tweed.

No one can question the importance of instruction. It is necessary to know many things; and though the intellect is unlimited in capacity, it contains no special knowledge at birth. We have to learn. Learning and instruction are thus essentially a process of putting something into a child—as we indicate when we speak of "cramming."

As the whole of this process is practically dependent on memory, and largely upon repetition, its practice is simple. But it is capable of any extension, and there is obviously no limit to the discussion and controversy which may arise over the

question what the child is to be taught. Is it to learn Greek or hygiene, or both? At what age should the Greek start? How many hours should be devoted to it, if any? Should some modern language be substituted for it, and, if so, what language? And should the object be to teach the speaking or the reading of this language? And so on, *ad infinitum*.

These are important questions, but in the main they are questions of practical convenience or of practical necessity. They do not belong essentially to the scientific plane, and they everywhere and always tend to divert attention from the fundamental questions to which we shall now proceed.

The Primary Purpose of Education to Bring Out What is in the Mind

For instruction is only an instrument of education—which is quite a different thing; and the misuse of the instrument may even ruin the material upon which it works. Essentially, education is not a process of insertion or intrusion or instruction, but of extrication. If a child's mind—that is, the developing mind of man—be likened to a portmanteau, education is not packing the portmanteau, as we commonly suppose, but unpacking it. We have failed to look at the problem biologically, but it is a biological problem, for it is a problem in the development of a living being.

Here, of course, we are prepared to look at it in that way, and so we may be willing to accept the definition of education which the present writer has now employed for many years. Education is the provision of an environment—no more and no less. It creates nothing whatever. Whenever we suppose that education has created something, we should ourselves learn to see that it has only provided the environment, the nurture, the opportunity, the stimulus, for the development of what was already potentially there.

The Complex Business of Providing for Each Child a Suitable Environment

At first hearing, many have supposed that "the provision of an environment" is a phrase which reduces the function of education unduly. But if we will begin by asking ourselves what man is, we shall soon see that the provision of an environment for the whole of man, in his young state, is a great and complex business.

Since the body of man is an animal, it shares all the environmental needs of animals. But since man is more than an animal, he has special environmental needs and susceptibilities of his own. A child and a puppy may live together in the same house. Both require air, light, cleanliness, and so forth, as part of their environment. Books and illustrated papers lie about a house; and there is a piano or a piano-player. What those books and papers contain, and what is played upon the piano, matters immensely for the education of the child's thought and eye and ear, but it is all one to the puppy. The dog is limited, but man is unlimited; and there is no limit to the provision of the whole environment for the whole man.

Our difficulty is to appreciate the potency of environment, and therefore of its provision, which we call education; and at the same time to realise that it creates nothing. Life grows and develops from within, in virtue of what it is.

A generation or more ago, when a wave of ignorant materialism passed over Europe, a celebrated German "thinker" propounded the doctrine that "man is what he eats." In the German, it runs, "Der Mann ist was er isst," so that this imbecility had the further advantage of embodying a pun. So obvious a lie needs no refutation, but we must be careful lest we practically endorse it in our theory of education.

Every Mind, Like Every Body, has Individuality and Needs the Right Environment

The man is what he is; and not only is he not what he eats, but what he eats needs to be swallowed, digested, and assimilated before it can serve its transient function of maintaining *him*. He may swallow and not retain, swallow and not digest, digest and not absorb, absorb into the blood, but not from the blood into the tissues. At every stage, we are gradually learning, he chooses and changes, selects and rejects, combines and parts, destroys and excretes—for the particular purpose of his particular physical life. If you throw rubbish on a heap you get a rubbish-heap, and a rubbish-heap thus is what it eats, but there is the difference.

Further, the physical body only supports the real life of man; and it is vitally important to see that the real life of man follows, as regards its special nutriment, the same laws as his body. Not even the mind is what it eats. It swallows, retains or returns, digests, absorbs, alters, forgets, combines, and parts, just as the body does; and every mind does all this in its own way for its own purposes, unlike every other mind that ever was or will be, just as the body does.

This is the meaning of individuality or personality; and this it is that the educator

must make up his mind, first to recognise, then to prize, and lastly to provide the right environment for, if education is to do what it should and must.

"To prepare for complete living is the function which education has to discharge," said Herbert Spencer; and we may now add that it can do so by the provision of an environment, and by this alone; that complete living is an ideal which includes certain essentials for all, but which necessarily differs in detail for everyone of us, since we are born different; and that, from the point of view of eugenics, education must include, or culminate in, education for parenthood if our work is to endure at all.

The Understanding of the Child's Mind the First Step in Education

That is a special topic of extreme difficulty, which requires, and will receive, separate treatment. Meanwhile, we must ask ourselves how this young live thing, the child, is to be prepared for complete living.

There can be no question that if we are to guide a child's growth we must, as far as possible, understand it. The essential of the teacher is that he or she "understands children"; the essential for the scoutmaster is that he "understands boys," and no one questions that. But plainly it means that we must first set ourselves, in our personal training for the profession of teaching, or in our national arrangements therefor, to the task which we have hitherto neglected.

The would-be teacher is set to study Latin and history, so as to teach children. He should first be set to study *childhood*, for *that* is the teacher's essential subject. And that is the subject which the effective and valuable teacher does indeed study, by reading, which is open to all, by observation, which is less easy, and by native sympathy, rarest and most essential; for the teacher, like everyone else that is not a duplicate of something, is born, and not made.

The Education of the Teacher the Real Beginning of Educational Reform

The first demand of the man of science, then, on the rare occasions when his voice can be heard in this matter of education, is that we shall radically and totally revise our teaching of teachers. From the standpoint of biology and psychology, he sees how intensely personal real teaching is. The Board of Education, which, until recently, only demanded of an assistant that she should be "nineteen and vaccinated," has yet to go to school itself, and learn the rudiments of its own subject.

The child's mind is a living thing, adaptable, supple, curious, keen, acquisitive, passionate, impelled from within, with the eternal thrust of Life behind it. The body needs environment, such as shelter from the wet and the dirt; but the proper environment for mind is mind, for soul is soul. What kind of shelter is the teacher's mind going to be against the danger and the dirt which lie in wait for the mind of a child? Such are the questions compared with which everything else that we spend money upon in this business is almost trivial.

No impartial expert can be found to do anything but deplore the difference between national education in ideal and in practice. Everyone wants education improved; but nothing can persuade either the public or the politicians that the first need in this matter is to do far more for the teachers, to train them more generously for their momentous work, to pay them better, give them smaller classes, and raise their *status* in proportion to our new appreciation of the importance of their work. From the standpoint of science, this is the real beginning of educational reform in this country.

The Ruthless Methods Long Enforced by the National Board of Education

When the teacher at last obtains the fair conditions to which his work will entitle him, what state of things will he be set to remedy? Let us take the answer in words lately written, in "Prevention," by the Rt. Hon. Sir John Gorst, formerly Vice-President of the Board of Education, and author of a memorable book on the "Children of the Nation."

He says: "Amid the flood of light which modern science has shed upon the methods of education, the Board of Education remains to a great extent still in primitive darkness. If education means the healthy growth of a child's body, mind, and soul, the most important agent in the process is the child itself. Its co-operation is, under the national system, shut out. The school kills its originality and its activity. It is, by nature, bursting with the instinct to do, to inquire, to discover; it is made to sit still, to hear and remember passively what the teacher tells it to think and say; the Government inspector pronounces such discipline excellent. In the higher schools the boys and girls are stimulated to study by a ruthless system of perpetual examination. They are not educated; they are not permitted to educate themselves; they are merely prepared for examination. The examination system pervades and rots the schools, the

universities, and the public services; it has become the greatest obstacle to the intellectual progress of the nation. No system of examination has been devised which tests adequately real knowledge, and real mental power; it tests information, often superficial, memory, and readiness to answer questions without expending much time in thought."

No teacher worth a straw needs an examination in order to know how his pupils stand, but the teachers are the victims of the system. It is not they that desire this method of cramming the child's mental receptacle with information and then applying the injurious emetic called an examination, but they have no choice. If we wish to realise how far such a method as this departs from the principles we have laid down, and, above all, from that which declares the teacher to be the essential part of the environment provided for the natural development of the child, we have only to ask the meaning of the word school, which we have taken from the Greeks.

There can be little doubt that, in nearly all respects, the educational system of Athens in her noblest days was the best ever yet practised by man. Scho'e, or school, means leisure. By school the Greeks meant the place of freedom and opportunity, leisure not in the sense of idleness, but leisure in the sense of liberty to be oneself—as we all are in our leisure time, for, as Dr. Johnson said, "No man is a hypocrite in his pleasures."

The Ideal of Leisure for the Child to Become Its Best Self

School, then, said the Athenians, is the place where one has leisure to be oneself, where the child has leisure to become itself. It is a view, ideal and practical alike, worthy of the nation which produced Socrates and Phidias and Pericles and Sophocles. And already we may see that the first principles, here laid down in our modern language, as introductory to the present discussion, were understood and practised by the Greeks.

The Eugenist believes and declares that people are naturally different. In spite of what critics in the past have said, he desires least of all the production of a dull uniformity of human type, which he knows to be in any case impossible of attainment. On the contrary, being also a student of society and its history, he desires all manner of capacity and aptitude and temper and interest, poets and pathologists, painters and philosophers, and pioneers above all; for he knows what the division of labour and the theory of the social organism mean, and that variety is not merely the spice of social life, but its very soul and spring. For him, therefore, the problem of nurture is, above all, the problem of permitting, encouraging, helping, guiding each child to be itself, and none other, its best and completest and most characteristic self, within the widest possible limits short of anti-social characteristics like criminality.

Plainly, therefore, this is the theory of education that the Eugenist must accept and advocate—the theory that it is the provision of the environment where the child has leisure to become its best self. The ease with which a trivial critic may make this old theory sound foolish is nothing to the point.

A Limited Number of Essentials that all Children must Master

We all understand that there are essentials which we must demand of every child, as to what it does and what it must not do. The same is true of the citizen also; but when these uniform demands, say as to clothing and decency, ability to read and write, and so on, are granted, for the convenience of everybody, we want the child and the citizen to be himself and none other, for himself and for us. And our business, or the teacher's, is to guide, correct, suggest, inspire, warn, direct; for if man be essentially a mind and a spirit, education must be personal and spiritual, or it is nothing.

Having reached this conclusion, the oldest and newest, the most evident and the deepest truth of our subject, we must turn to study the socio-political structure which the nation has devised, or which has somehow devised itself, for dealing with the problem in its national aspect. The state of things is utterly deplorable, though anything but hopeless. It calls for condemnation in the severest terms, which are, indeed, levelled against it by all serious and thoughtful persons, but we must clearly understand that no individual or individuals can be blamed.

The Ominous Want in this Country of an Education Controlled by Educationalists

The blame is collective and national, in that we have no real belief in education in this country, though we have only to glance across the North Sea for the most tremendous, if not ominous, object-lesson that an unconvinced people could desire, and though the magnificent results attained in Germany, results which, by general

MODERN METHODS IN THE SCHOOLS

THE TRAINING OF HAND AND EYE IN A CLASS IN THE OPEN AIR

THE PHYSICAL DEVELOPMENT OF THE CHILD IN HEALTHFUL SURROUNDINGS

From photographs by courtesy of Dr. Ralph Williams, Chief School Medical Officer, Sheffield.

consent, have made modern Germany, are based, above all, on the work of the great pioneers in education and psychology which this country, beyond all others, has given to the world.

The acting and efficient head of our Board of Education is a permanent official, who must necessarily possess the many valuable qualities of a permanent official, together with their corresponding defects. The country has been by no means unfortunate in this respect of late years, and no personal allusion of any kind is made to the late or new occupant of this post, or to any future occupants, when we say that, from the standpoint of science, the acting head of our system of education should be an educationalist.

The Most Difficult Science in the World Regarded as a Minor Political Concern

Nothing of that kind has ever been tried in this country, or has even occurred to politicians. On the contrary, the most distinguished educationalist we possess, Professor Michael Sadler, whose name is honoured wherever education is honoured, was compelled to leave the official service of his country in this cause, for the sufficient reason that being, by some strange chance, an educationalist in the education service, he could not hold his peace about the folly and the ignorance which he saw on every side. Closely parallel treatment has been allotted to Sir John Gorst, whose name stands apart among education Ministers, for his interest in the subject and the scientific study which he has devoted to it.

The members of the Board of Education have spent their lives, not in educating, as one might suppose, but in the Civil Service. The figure-head of this system is, as a rule, a rising young politician, who accepts the post *en route* for higher office.

The Supineness of the Public with Regard to Real Educational Questions

Though education is the most difficult practical science in the world, and though the nation lives or dies at any time by the total quality of its education above all, the Minister of Education holds a minor post, and receives a mere fraction of the salary paid to him whose care is not just the children of the nation, but its ships, its roads, its money, or its guns.

No defender of the fact can be found, but there it is and there it will remain until public opinion is so educated—and the writer has a great hope within him as he pens the words—that Parliament is compelled to honour education and its ministers, from the highest to the lowest, if we are to maintain our race and its ideals in the modern world, where mind is every day increasing its mastery over matter.

As has been pointed out on the highest authority, " it would take a new Minister of Education, however great his talents, years to understand the machine of which he is the nominal head; and, meanwhile, to avoid a fiasco, he must do as he is told by his departmental advisers." Except where religious feeling can be aroused, education does not count in Parliamentary or municipal elections. In so many other cases, the critical student can only say, as has so often been said, that a country has the system of government, or anything else, that it deserves, but in this case the incidence of our deserts is not upon our heads. It is the children that have the system of education which *we* deserve. Only public opinion can remedy the evil, and only through its influence upon politics can this be done.

At present, the only bodies in the country that concern themselves with the matter are the various religious organisations which are interested in what is called the " education question."

A Great Public Question that is on the Programme of no Party

That, however, important and difficult though it be, is not the question of education; and the writer may be permitted to repeat an observation which he made in the public Press some five or six years ago, when Parliament was discussing these matters. So long as the " education question "—*i.e.*, the question of religious instruction in the schools—was under discussion, all parties and sects, as represented in Parliament, were flagrantly and evidently guilty of lack of charity, of envy and malice, and mutual hate; but when the religious question was passed and the necessitous state of too many ill children came to be discussed—a mere secular matter—these same disputants were transformed, really caring for the children, agreeing with each other, crediting each other with charity. So that, if true religion is to " do justice and love mercy," it seemed that Parliament had only to leave the religious question in order to become transformed from an irreligious into a religious assembly.

Experienced and sincere politicians are of opinion that an educational campaign in the country would probably fail. The party that took it up would risk offending

some vested interests, and would be accused by the other party of turning what should be a national question to party-political profit. Therefore, the reform of our educational system has the honour and the misfortune to appear upon the programme of no party, sharing that distinction with many another question of primary national importance.

It is simply useless for the public to blame politicians for this. The politician is at the mercy of the public; and if he loses its favour he drops out of political life. For the public to round upon him in such cases as this is simply to repeat the trick of the naughty boy who says, " It's not me," and tries to throw the blame on someone else.

But the School Doctor now Clears the Way as a Pioneer

But nothing can permanently arrest the course of life. It has burst through and beyond the hardest and most rigid of its own products, the shell of the mollusc, the rigid automatism of instinct; and it is not for ever to be manacled by mere red tape. The dawn in our schools dates from those years in which the state of the children began to be discovered, and science, in the shape of the school doctor, entered them at last.

That is the beginning only, but it is the beginning of great things. The elementary problems of medicine and hygiene—they really are elementary in this case—must soon be solved; the psychologist and the educationalist must follow along the path which the doctor first clears for them with his throat-scraper and tonsil-clipper, like the weapons with which the pioneer clears away the undergrowth, before the engineers and the builders can run their rails and do their constructive work.

Education has not Failed, but has been Half Strangled by its System

On all hands people are heard to deplore the bursting of the bubble called education. The writer has again and again heard the failure of education in this country to do what the beginners hoped used as an argument for " nature " as against " nurture," for heredity as against environment. Speaking as a professed advocate of the importance of heredity and Primary Eugenics, he has always been bound to protest that this argument for its importance is not a good one. It is not education that has failed, but our educational system; and already the signs of a new era are upon us.

Here, again, it looks as if there were some reality in those divisions of time which men call centuries. The dawn definitely came with the twentieth century. The nineteenth gave us great heralds of the dawn, from Herbert Spencer, whose ideas are now just beginning to be embodied in our practice, downwards to the unnamed multitude of faithful teachers who sought to do what they knew to be living work even inside the dead shell and strangling tape that bound them. But it is only now, more than half a century after Spencer wrote, that we are doing what he told us. Once again let us quote a paragraph from Sir John Gorst, who stands honourably alone, in his veteran age, among those who are, or have been, politicians in this matter. He says:

"There are teachers, of all ranks and of both sexes, who have in spite of all discouragement established schools in which real education is given. There is a grammar school in the heart of mediæval Cambridge in which classics are so taught that boys learn to love and cherish the literature of Greece and Rome, instead of learning to hate the intricacies of grammar and prosody; they do not cast away their books into a cupboard when they leave school or the university.

Examples of Real Education that has Survived Official Repression

"There is a country village in Sussex where the boys and girls of ploughmen and shepherds are allowed to grow into men and women endowed with knowledge and possessed of intelligence and capacity, and fit to be good ploughmen or shepherds, or fill with credit any 'station of life to which it shall please God to call them.' There was some years ago an infant school in Peckham, of which the mistress is now unhappily dead, where drawing, painting, and clay modelling, instead of reading, writing, and arithmetic, formed the curriculum, and from which the children passed into the older school, according to the testimony of the Government inspector, better readers, writers, and arithmeticians than those from the then customary book-school for infants. These brilliant lights which are increasing and spreading over the land are the greatest hope of British education. They burst forth in spite of repression of a red-tape official bureaucracy, central and local."

It is inevitable that, amid the widespread dissatisfaction with what we at present misunderstand by the name " education," there should be much putting forth of ideas which have no substance, which emanate

from cranks, are suitable only for very few children, or are commercially designed to attract parents. Others, again, may be absolutely valid, but are not yet proved, or have not yet passed the experimental stage. Grave responsibility devolves upon the writer who should set forth as the verdict of science what is still dubious. Here, therefore, such difficult problems as co-education will be set on one side. Instead of arguing for or against this or any other theory about which authorities of rank still differ, we shall state those few and definite propositions regarding educational reform on which the verdict of psychologists and educators is everywhere unanimous.

Education Should Begin with Play and Physical Training and End with Books

Education should not begin with books, but end with them. Education of the intellect begins with the senses, and with the training and interpretation of sensation, perception, and response. This is the secret of Nature's method of training the intelligence and its responses, which is by play. The comparative study of mankind and the lower animals has proved this once for all.

Play is not only the outlet for superfluous energy; it is the child's practice and rehearsal for the work of life. The cat that systematically educates her kittens by play is our type in this matter. All children should play, and should be taught to play. The individual play of the very young child will, in due course, be discarded for combined games, which offer opportunity for the education of higher and more precious things than the senses and the intellect—education of will and self-control and character, constituting personality.

The Adaptation of Methods of Education to the Individual Child Essential

Combined and constructive play may readily lead to manual training and education, in making all manner of things—including drawings and diagrams and maps and sketches—that educate every valuable quality of the mind. The thing made stands in judgment upon the faithfulness of the work; that is the natural "examination" for which everything is to be said.

All authorities everywhere are agreed that manual training, from the wool-pictures of the kindergarten upwards in fifty directions, should be far more prominent in education, and that this is the most needed reform in our curricula.

Action, construction, achievement—these are what the child desires, these are what we desire of the child. The hand has been the tutor of the brain in the history of the race, and we have underrated its almost essential importance as a tutor of the brain in the development of the individual. To give the child opportunities to make what it will and can, to protect and suggest and discipline and encourage while it does so, this is the "provision of an environment" in which the child's individuality can grow wisely and well.

Meanwhile, the individual child is the infallible judge of all our theories. The most urgent danger of educational reform to-day is that we shall be so pleased with our new methods as to determine that all children must be fitted to them as ruthlessly as ever they were lopped and stretched to fit the Procrustean bed of book education in the past. "It takes all sorts to make a world," and there is no need which Nature has more generously supplied. If all children are to have the book education of the past, or all are to have the system, beginning with the hands, which modern study has certified, undoubtedly a far larger proportion will suffer under the first than under the second; but there is no system of education, nor ever will be, that suits all children. Or if ever such there be, life will be played out.

The Educationalist's Priceless and Unique Material Fashions the Race

But life has only lately discovered, in man, the open road of advance; and in no speci s in the world, animal or vegetable, can we witness a tithe of the variability which man, so constant in mere physique, exhibits in his nervous system and psychical constitution. This inherent variability, which is the despair of the educationalist with a system—*any* system old or new—is the very hope of the world, the essential root of progress, the very stuff of which the Eugenist seeks to build and fashion the race that is to be. Of such is made the "Kingdom of the Future."

Let us, then, beware. This material that we undertake to handle is priceless and unique, perhaps; and though there are countless ways of going wrong, there is only one way of going right. In any case, our functions are negative, directive, protective, rather than creative or constructive. We can assuredly destroy, but we cannot *produce*—only *permit*, and nourish. And, indeed, those who have seen and tried and yearned the lon est may come to believe, perhaps with a sigh, that the educator can do no more—but it is much—than guard and guide, watch and pray.

THE LIFE-STORY OF WORLDS

Changes That Can Be Seen or Inferred Throughout the Brotherhood of the Sun

DOES HEAVENLY MOTION RUN DOWN?

We have seen the fashion in which it may well be believed that worlds such as ours were made, and have traced the probable course of events from the "fiery clash of meteorites" onwards to the formation of such planets as the Earth, or Jupiter, or Neptune, in a solar system such as ours.

At this point the science of astronomy would have had to give way, until the most recent advances in knowledge, and allow geology, the science of the earth, to take up the tale, as regards the earth alone. The earth is our home, we know far more about it than about any other planet, and it has a due place to itself in the present work, but the earth is also one of the heavenly bodies, as Copernicus taught the modern world; and the new astronomy has learnt so much about some of the other heavenly bodies that we have reached one of those great points of new departure which are always formed at the junction of the paths of two sciences. Geology and astronomy join hands, the student of the earth gives invaluable hints to the student of the other planets, and the student of the other planets is able, by his opportunities for comparing one with another, to help the geologist with his local problem.

Here, then, the artificial demarcation between two great sciences breaks down for a while, as it must do if they are to advance, and the astronomer is entitled to treat the earth of the geologist as just one of the heavenly bodies, just one of the planets, the life-history, as we may call it, of which we must now discuss.

We have seen how the planets were probably born. Let us now see how they fare. We have our own earth, which we see from one point of view, and we have other planets, seen from another point of view; so that, for instance, we can see and study the South Pole of Mars, though we have not yet discovered our own South Pole; and these other planets differ widely in size, distance from the sun, chemical composition, possession of satellites, presence or absence of water, solidity or fluidity, possession or deprivation of an atmosphere, and many other points. Our knowledge has reached the stage, indeed, at which the comparative study of the planets and their histories becomes possible, and we are entitled to carve a section out of astronomy—which is literally the law of the stars—and call it planetology, the science of the planets.

The study of the origin of the solar system, including the nebular and meteoritic hypotheses, has presented us with planets already formed, in a fashion which we seem to have traced some details of; and now we must survey and compare the existing planets, in the light of those ideas, to see how they have come to be what they are, why they differ as they do, and what is likely to become of them.

The meteoritic theory gave us the possibility of planets which were hot, and which, as they grew by aggregation or "fiery clash of meteorites," became hotter. Those whose making involved most clashing, and most furious clashing, those made by the coming together of very large or numerous masses of matter, would be not only the biggest but the hottest. The smaller ones, on the other hand, would have less heat to lose, and would lose more quickly what they had, on the principle, so wide in application, "from him that hath not shall be taken even that which he hath." An immense aggregation like Jupiter would be something like a sun to start with, and what we call the sun would only be a more colossal example of the same thing. We have already arrived at an idea which is still novel to almost everybody.

We all now agree that the earth is one of the planets, and we rightly distinguish between the planets as a whole, which go round the sun, and the sun they go round. But now we are to learn that any other distinction than that of relation in space is really invalid. The sun, but that it happens to be in the midst of the planets, is only another planet, the biggest and therefore the hottest, and the slowest to cool, but essentially similar, nevertheless.

All the Planets Sunlike Once and Some Sunlike Still

Our theories of the solar system, and our studies of its formation, have been to little purpose if we do not now see that the solar system is a whole, all spinning together, like a kind of marvellous top, of which some part must be more central than the rest. The vast contrast between the sun and the planets, so far as their appearance is concerned, only depends upon the fact that the sun is so much bigger, and *therefore* so much hotter, having gathered together a greater store of heat in the first place, and having lost it much more slowly. It is only a matter of degree.

If we now look at the largest of the planets, we find evidence which suggests that they are almost sunlike still, and we begin to see that there may have been—must, indeed, have been—an early stage in the history of all the planets when, so far as temperature and surface were concerned, they must have practically been suns. Jupiter to-day, so far as his temperature and bulk and composition are concerned, and his giving forth of light and heat *of his own making*, and not merely reflected from the sun, is quite capable of playing the part of a very effective and magnificent sun to his eight moons—or planets, as we might almost call them. Here is a kind of solar system within the solar system, just as the solar system is a little cosmos within the great cosmos.

The Common Origin and History of Sun, Planets, and Moons

We said that the earth and all the other planets were to be surveyed and compared. But now it is clear that there is no real reason for omitting the sun from this comparison. Sun and planets are profoundly contrasted in certain mechanical relations, but if we consider them as individuals they must all be compared, and all will help to solve the problems of each. Nor is there any reason to deny the right of "the" moon, or of any moons, to a place in this comparison, and the meteorites must be admitted too. All are of fundamentally similar origin and composition, and all have fundamentally similar histories, the differences in which are as valuable as the similarities.

Indeed, so far as the sun and the planets are concerned, we see that a familiar figure of speech is no longer justifiable. Looking at the planets revolving round the sun, and also believing, perhaps, in the gaseous-nebula theory, on which the planets have been successively "born," so to say, from the rim of the solar nebula, we incline, very naturally, to speak of the "sun and his family," to look upon the relation of the sun to the planets as paternal, and to assume a sharp and absolute contrast between them, as individuals. There is no such contrast, and the meteoritic hypothesis has prepared us for a figure of speech which may here be suggested as much more accurate and illuminating. The sun and the planets are similarly derived from the meteoritic composition of a spiral nebula.

The Sun the Big Brother of All the Members of the Solar System

The sun is thus in no sense the father of what we have called his family. His relation is not paternal, but fraternal; he is the big brother of the planets, and, if you will, their ringleader, as a big brother well may be. Just because he is big, they revolve round him, and he is their ringleader in the tremendous enterprise upon which the solar system is engaged, as it flies onwards through space at the rate of ten or twelve miles in every second of time.

We are thus prepared to study the planets, in their earliest stage, as none other than small suns. And we are therefore to recognise two stages in their history, with a gradual transition, of course, between them. These are the self-sustained and the sun-sustained stages of a planet's history. There is no sharp or even real line between them, and we must not begin by making that mistake.

The planet in its earlier, self-sustained stage was yet shone upon by the sun, probably by a much brighter sun than we see now, though it is difficult to argue certainly on that point. Further, the planet in its sun-sustained period, giving no light of its own, as in the case of the earth or Mars, yet has heat within it, and is thus also self-sustained. No student of geology, who knows something of the fires beneath us, can look upon the earth as entirely dependent upon the sun for its heat. Yet, when these important

considerations are allowed for, it still is evident that there is a vast difference between a hot, expanded, glowing planet like Jupiter, which is still so nearly a sun as to be described as self-sustained, and such a body as Mars or the moon, whose surface is solid and depends upon the sun for the light we see it by. Jupiter provides us with what is, perhaps, a typical transition between the earlier and later phase, and the light we see him by is partly his and partly the sun's. Let us now study the history of a planet more closely, with the idea of these two stages in our minds.

Elements Exist Separately, and Compounds Cannot be Formed in Heat Like the Sun's

A vitally important sequence from the earlier, or sunlike, to the later stage is to be expressed in terms of chemistry. At high temperatures the atoms of matter cannot unite with each other; oxygen atoms and hydrogen atoms cannot even combine to form molecules of water. No compounds can exist, only elements as such. That is what we find in the sun. No compounds we know could exist at the estimated temperature of the sun; and the spectroscope confirms this view.

We may similarly argue that the earliest, or sunlike, stage of a planet would find its elements uncombined with each other, just as the geologist finds elements such as chlorine and sulphur, carbon and hydrogen, produced by volcanoes and geysers to-day —"pathways to the past," which suggest how intensely hot the temperature of the interior of the earth must still be.

But as the surface of a planet cools, chemical combination between the elements becomes possible, and compounds are formed. The first are probably simple ones, such as those which form carbonic acid gas from carbon and oxygen, and water from hydrogen and oxygen. Later, the temperature may fall enough for the existence of such complicated molecules as we find, in the case of our earth, in the bodies of living creatures. Not until the temperature had fallen could the life-bearing epoch of the planet's history possibly begin.

Small Planets May Grow Old Before Large Planets are Ready to Sustain Life

We know how readily heat destroys life, because it breaks up the molecules upon which life depends for its manifestations. Thus, just as there can be no water upon the sun, so much less can there be life, as yet; though, if we rightly grasp the big-brother idea of the sun, we shall see that a life-bearing destiny may yet await the present supporter of life on other planets —supporter so generous that life upon himself is impossible. As for Jupiter, even though water may be possible at its present temperature, it is very doubtful whether life could yet display itself there on any such conditions as obtain here; that stage is yet to come.

These chemical considerations are not all. There is also the question of the physical state of a planet in its successive stages—not least of its atmosphere, which in early times may be so dense that no light from the sun or any other body could fall upon the recently solidified surface of such a planet.

Small planets, such as the earth and Venus and Mars, are already so old—as a small animal may be old at seven years, when a larger animal is not half grown—that we cannot learn much of their past from direct study of them alone. Larger planets, like larger animals, are longer-lived, and it is to these we turn for present illustrations of the past of such planets as the earth and Mars.

Has Jupiter Reached the Stage When Its Constituent Elements Can Solidify?

It has been known for more than two centuries, for instance, that different parts of the surface of Jupiter travel independently of each other—reminding us of the moving staircase device. One belt of Jupiter's surfaces may rush past its neighbour at the rate of perhaps four hundred miles an hour. The planet clearly has bright and dark belts, largely independent, constituting its surface. That is enough for us now. It shows that the surface of the planet cannot be solid, and it is indeed largely, if not wholly, gaseous, like the surface of the sun. The bright belts may perhaps be clouds of water-vapour, like the clouds in our own atmosphere, but they behave very differently; and the atmosphere of Jupiter is plainly much more like the atmosphere of the sun than our own, and we may very well doubt whether there is any solid surface beneath it.

Certainly it looks as if the planetary transition from a sunlike to a merely planetary state, with the formation of a solid surface, occurs under an atmosphere so dense that we cannot see it, and that no light from the sun could penetrate it. These suggestions derived from astronomy must be intensely interesting to the biologist when he reflects upon his great problem of the origin of life.

Might there not have been warmth enough to make life possible, and incubate it under a cloudy atmosphere such that the sun's rays could not penetrate it? May not life have originated, upon the earth, in the self-sustained stage of our planet, even though nearly all the earth's life is now sustained by the sun? And what, perchance, may now be incubating beneath the gaseous envelope of Jupiter, or may soon begin to do so? Here, surely, is an illustration of the value of joining forces between astronomy and geology for the solution of a problem to which science must constantly return.

Saturn, Uranus, and Neptune illustrate, though in more advanced stages, due to their lesser size, the self-sustained, or almost sunny, stage of a planet's history. It is, indeed, quite conceivable that any of these planets may have reached the life-bearing stage already, under their veil of cloud. But when we turn to the smaller planets, with their shorter span of life, the case is different. We can only hope that the geologist will offer evidence that at least one of the planets was once in such a self-sustained stage as Jupiter is in now.

The Size of the Sun Makes it Young as a World, not yet Cooled Down

The reader of the chapters on the Earth will not find it difficult to believe that the earth has been far hotter than it is. The temperature at its surface may once have been such that oxygen and hydrogen, as in the sun to-day, could not combine. Later, water undoubtedly existed, but the surface was so hot that it all had to exist as a vapour; and we can even indicate the levels of the earth's crust which first show the action of liquid water—when it became possible for liquid water to exist. In short, the modern geologists are drawing for us a picture of a past earth, the surface of which was very hot, but with very little light; and there is evidence from the side of the biologist to show that early forms both of animal and vegetable life would agree with such conditions—early plants which love warmth and shade, early animals which possessed no eyes, for light had not yet penetrated from the worlds beyond to this little world of ours. Survivals of this eyeless sort—to whom, say, the revelations of astronomy mean nothing—are to be found a-crawling here and there even to-day. And this picture of the earth, at some remote epoch in the past, is notably in agreement with what the newer astronomy describes as the present condition of the surface layers of the largest planets in our system.

The sun, then, though our big brother, is young in a profound sense, for it is in an earlier stage of evolution than any of its smaller brothers. Jupiter comes next, then Saturn, until we reach very small worlds, like Mars or the moon, which have already all but run through their lives, and hang in the skies as a *memento mori* for us.

How All the Planets Were First Self-Sustained, and Then Became Sun-Sustained

Now let us consider the period of transition from the first to the second stage. As the sunlike planet cooled, its atmosphere would largely condense, just as the water in the earth's atmosphere condensed long ago to form the seas; and two notable consequences would follow. We know that the earth's atmosphere, even now, is a blanket that keeps us warm. Much more so must this be true of the dense, opaque atmosphere of a planet's earlier stage. The precipitation of the greater part of this atmosphere would be like taking all the blankets off one's bed, and leaving only a semi-transparent sheet. The heat from within would escape, and the light from without would enter. The formerly more self-sustained planet now becomes more sun-sustained. And this, in popular language, is where we come in; this is the cue for the higher forms of life, mainly sun-sustained, to enter and play their parts upon the stage of any such world.

Here, evidently, is the beginning of climate and seasons, with all they mean for life, and its adaptation thereto. Trees appear which shed their leaves, accept the winter, and go to sleep till spring—unlike those earlier forms, of which some representatives still survive, that seem to show no trace of the existence of any seasonal change to which they required to respond.

Does Water Disappear From Planets, and, if so, Where Does It Go?

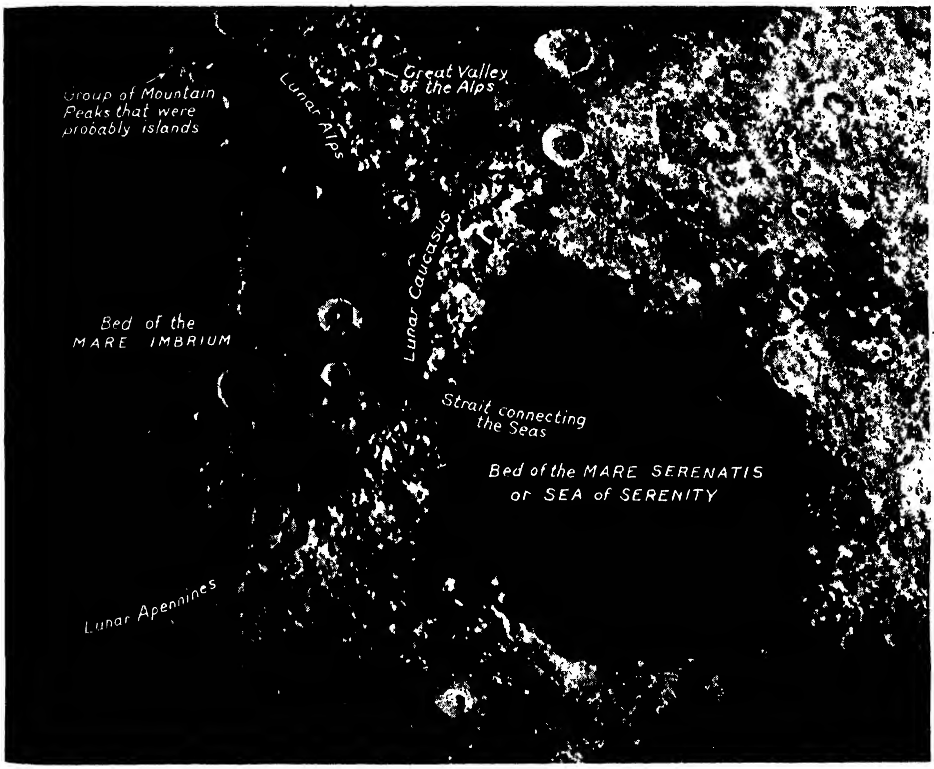
Water, in its liquid form, plays its essential part in all these manifestations of life; and the student of planetology might well devote years to the study of the water of a planet alone, beginning with its first formation by the union of oxygen and hydrogen when the temperature fell low enough, continuing with its partial precipitation upon the surface in liquid form, and going on to ask what becomes of it. For the water of a planet disappears.

If this indeed be so, it is a stupendous fact. When we come to the detailed study of Mars, we shall see certain consequences

of it. Meanwhile, we are concerned with the general evidence that the gradual loss of water is a necessary part of the history of, at any rate, the smaller planets. What may happen to the water, or the future water, of the larger planets we can only dimly guess. Being so large, they may, perhaps, escape the fate which appears to be already visiting their smaller and older brothers.

In studying the self-sustained stage of planetary history, we have naturally paid special attention to the larger planets, which appear to be in that stage. In enough. Much more so does it appear when we realise that the surface of the moon displays features which really bear no reasonable explanation but that they are the dry beds of former seas. That is enough for us at present, regarding the moon—that it is now waterless, and must once have had water.

Closely similar is the evidence of the surface of Mars, a planet which, though larger than the moon, is much smaller than the earth. No problem is here, as in the larger planets, of trying to peer through a dense atmosphere. The moon has no



THE BED OF AN OCEAN ON THE MOON, SHOWING ITS FLATNESS

studying the sun-sustained stage, we naturally turn to the smaller planets, and also to such a body as our moon, which should teach us the kind of pass to which our earth, for instance, is likely to come.

This is where the evidence regarding the history of a planet's water stares us starkly in the face. The moon must be absolutely, or all but absolutely, waterless. On this point there is no controversy, all astronomers being agreed, and the evidence being conclusive. Now, if the moon was once part of the earth, whose oceans we know so well, its waterless character is remarkable atmosphere at all, and nakedly displays its arid surface. The surface of Mars is scarcely less visible, and there, also, are features which were confidently taken for oceans and seas when they were first observed, but which, we know, are now quite dry. Astronomers can no longer doubt that water is present in Mars; but the fact that this was very doubtful, and that only the genius and patience of Professor Lowell and his helpers have been able, by delicate spectroscopic evidence, to demonstrate it, suffices to show what an extraordinary contrast there certainly is

between the surface of Mars and the surface of the earth in this vitally important respect. The presence of some water upon Mars may be demonstrable, and may be of overwhelming importance from the point of view of the possibility of life upon Mars; but the astonishing scarcity of whatever water there may be, together with the evidence of abundant former water, and the similar evidence derived from the moon, entirely justifies the assertion that, in the course of its sun-sustained stage, a small planet loses its water.

The Clash of Controversy—the Presumptions of Astronomers and Findings of Geologists

We shall not here enter upon the controversy between Professor Lowell and the geologists regarding the facts of our own earth in this respect. The balance of evidence may, perhaps, appear to incline to his view that the earth is slowly losing its water, as the moon and Mars have certainly done. At least, we are entitled to say that, whatever the geologists may find definitely shown by the earth, the astronomical evidence, as we have outlined it, creates a very strong presumption in favour of the view that the earth must be going through a similar evolution to that which the comparative study of the planets seems so clearly to demonstrate. At any rate, if we make a comparative survey of the condition of all the planets and our moon, in the matter of water and of atmosphere, we seem to see it clearly stated that in their later stages the worlds lose both their water and their atmosphere.

Naturally, we ask how this can occur, for we have not forgotten the law of gravitation, which would seem much more likely to draw new particles to a planet than to permit it to lose what it already possesses.

Can Gases Fly Beyond the Power of Gravitation to Bring Them Back?

The first contributor to this subject was the English student Dr. Johnstone Stoney, who died very recently at a great age. Studying the behaviour of a gaseous collection such as our atmosphere, he saw that, under certain conditions, particles of such a gas might altogether escape and fly away into outer space. The molecules of a gas are all in violent motion, which involves collision very frequently. Such collisions will sometimes lower the speed of the colliding molecules, sometimes accelerate it. Here, then, are possibilities which may be able to counteract the force of gravity, with just the results which Jules Verne imagined, in the making of a gun that could shoot a projectile to the moon. To reckon the required initial velocity of such a projectile is only a matter of mathematics. Just so in the case under discussion.

We can study the gravitational control which the moon, the earth, Mars, or any other body of which we know the mass, is capable of exercising. It can be shown, for instance, that molecules of gas reaching the upper limits of our atmosphere at a speed of about seven miles a second—which is a quite possible and, indeed, actual speed, as we learn from the study of gases—would permanently leave the earth. This is the "critical velocity" at which the earth can no longer retain a molecule; and physicists are now agreed that this perpetual drain upon our atmosphere actually occurs. Needless to say, this remarkable discovery, made by the physicists without reference to any astronomical considerations, consorts admirably with the theory of planetary evolution which modern "planetology" seems to indicate.

How the Life-Bearing Stage of a World's Existence Depends on Size

For when we compare the planets, including the moon, we find their condition corresponds to what we should expect, remembering that the lighter gases of an atmosphere will be the first to go, and that, the more massive the heavenly body is, the longer can it retain its clothing of gas. Water, for instance, must go before oxygen; and we must remember that water is a normal constituent of our atmosphere, even though most of our planet's water be in the seas.

Thus the largest planets have the densest atmospheres, the earth has less, Mars has very little, Mercury and the moon have none at all, and the same is true, so far as can be discovered, of the other moons in our system. It looks as if every one of the satellites of the planets were already dead —the children dying before their parents, because the children are smaller and therefore age more quickly. The death of the moon is evident to all eyes. Professor Lowell has no need to urge from the presence of the lunar craters that its past must have been very much more lively than its present, for there is abundant other evidence for that assertion. Of course, if the lunar craters be, indeed, craters, then the argument is warranted.

Many astronomers now suppose, however, that what we call the craters and extinct volcanoes of the moon are nothing of the

sort, but the consequences of the impact of meteorites. Professor Lowell, as a foremost advocate of the meteoritic theory of the origin of the planets, can scarcely look askance at this theory of the lunar craters. We may add, also, that his argument from the smoothness of the lunar ocean beds is not invalidated. He points out that these uniform beds must evidently have been protected by something from the volcanic fury and flows of lava which seem to have disturbed the other parts of the moon's surface, and that this something must have been the water of which there now remains no remnant.

But if we suppose the markings of the moon to have been rather due to the impact of meteorites—unchecked by any protective atmosphere worth mentioning—we may still suppose that it was the presence of water which protected the old sea-beds from such assaults and kept them smooth. The argument for former water thus remains.

We have yet to study the individual planets, each for its own sake. Meanwhile, it may surely be argued that this comparative study, which surveys them all, taking the great conclusions of geology in its stride, constitutes an advance in the dignity and unity of science. Really, we know very little yet, and are only groping, but there is enough knowledge, and enough coherence between its parts, for us to frame a provisional theory which is sufficiently complete.

Are Day and Night and the Seasons Destined to Cease?

Tidal friction has to be included, if the complete sequence of future events in the solar system is to be outlined, and it teaches us that, just as Venus and Mercury already turn one face constantly to the sun, their day and their year being thus equal in length, so also the other planets are tending to a similar condition, with its inevitable abolition of the rhythmical changes of day and night which make our earth, for instance, what it is for us.

Absolute uprightness of rotation in their orbits is also, apparently, the destiny of the other planets, as already of Mercury; and this means the end of seasons such as the earth's, which everyone knows to be due to the obliquity of her axis.

Every tendency is thus towards stability, rigidity, planetary death; while loss of water and of air, as in the case of the moon, must mean the end of a planet's life in the stricter sense of the word.

Finally, if the sun be really the big brother of the planets, and ultimately subject to the same laws, it is destined to reach such a stage as Jupiter now exhibits, and ultimately to grow cold. Possibly the sun is now rising in temperature, though losing its store of heat; but the time must come for the sun, as it has already come for the planets, when its temperature begins to decline. Thus, no matter whether we accept the nebular hypothesis of Laplace, or any later form of it, or the meteoritic hypothesis of Lockyer, or any later form of that, we eventually reach the stage of a sun as dead as the moon is now. Only its greater size is accountable for its longevity and the protracted character of its developmental stages—like an elephant, say, compared with a mouse.

That Which Lighted Life's Spark can Light It Again

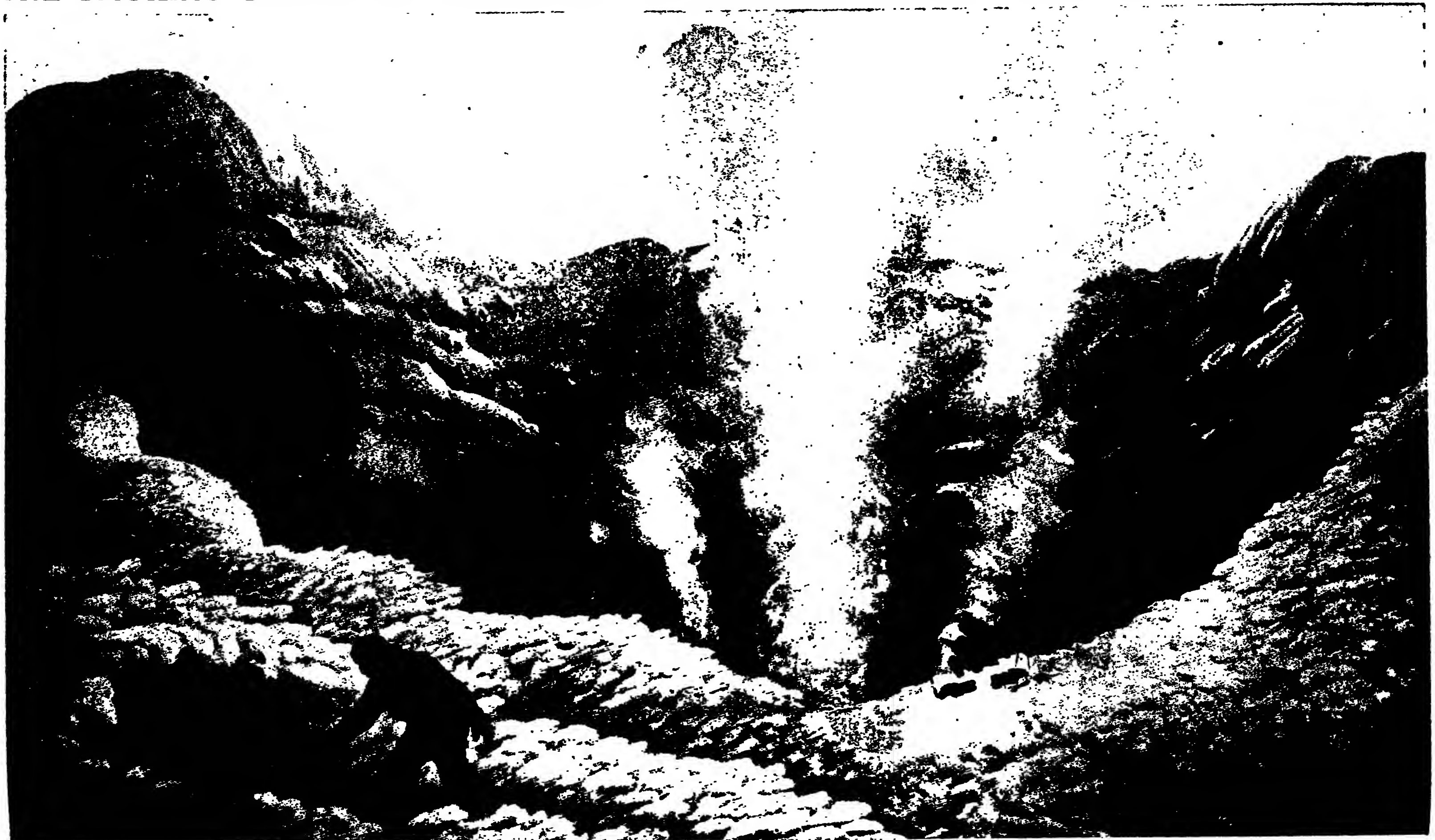
The end is sure; more sure, now that we have looked at the evolution and destiny of its smaller brethren, than before we realised its fundamental identity with them. But we have already seen cause to believe that the universe does not run down, that birth everywhere springs from death, and that, if the sun ends as a cold and dead body, what but a cold and dead body was that with which the history of the sun began?

And where, in the universe, is all this happening? The sun and his system are in motion. What is their present relation to the rest of the universe? Whence came they, and whither are they going? These are questions which must interest us if they be asked of any sun, of any star; for to understand the movement of even one sun or star would perhaps be to have a key to what is apparently so helter skelter in the paths of the stars.

Can It Be That Man's Home After All is a Centre of a Stellar Scheme?

Much more does the question concern us when it is asked of our own system; for wherever the sun and his system go, there is the theatre of man's activities; and the answer to these problems of the "proper motion of the sun," in relation to the stellar universe, will teach us the physical relation of our earth and ourselves to the rest of things. We began by denying, summarily, that the earth is the centre of the universe. What if we should go on to discover that perhaps the solar system, at any rate, does now occupy none other than a central position in, at any rate, our system or "universe" of stars?

THE SMOKING CRATER OF COTOPAXI, THE HIGHEST ACTIVE VOLCANO IN THE WORLD



The crater of this volcano in the Andes of Ecuador is [illegible] feet in diameter and sends out into the atmosphere as much carbon dioxide as the city of Paris.

THE AIR IN WHICH WE LIVE

Where the Atmosphere Came From. Its Height, Importance, Composition, and Permanence

AN INDISPENSABLE CONDITION OF LIFE

THE earth does not end at its crust. The tops of its mountains and the surfaces of its seas do not define its true circumference. It carries with it on its journey through space a mighty volume of gases known collectively as the air, or atmosphere. However fast the earth flashes, however rapidly it spins, its gravitative force still grips these gases. One would think that as it rushes eighteen miles a second through space, spinning like a dancing dervish, the atmosphere would be swept off it; but, in the first place, there is no friction in space, and, in the second place, gravitation is quite strong enough to grip the gases to it.

How high the atmosphere is it is difficult to say. Meteors have been observed in it at a height of two hundred miles, and that is the limit commonly ascribed to it; but no doubt molecules of lighter gases extend as far as the earth's gravitative reach extends, and some may even transgress that boundary line and escape into space. It is not so easy, however, as some people think for molecules of gas to escape into space, for it must be remembered that at the outer limits of the atmosphere the molecules are exposed to the paralysing cold of space.

The air extends not only upwards but downwards: it penetrates for some distance into the ground, and it is found in solution in all natural unboiled water.

Now, what does this great gaseous envelope mean? What is the *raison d'être* of the atmosphere?

The gases of the atmosphere perform most important geological and biological functions. Without them there could be neither animal nor plant life on the globe. All functions of life, motion, assimilation, reproduction, depend on a supply of these gases, and especially on a supply of oxygen. All living things, whether microbes or mastodons, cabbages or kings, fishes or caterpillars, require a conjunction between their corporeal substances and the oxygen of the air. This conjunction is the fundamental fact in the process of respiration, and is of the same nature as combustion; it consists, like combustion, in the wedding of oxygen and carbon and in the production of the gas carbon dioxide. All plants and animals respire in this fashion, and the touch of the oxygen on the cells of living things is like the touch of a finger on a trigger: it sets going the mechanism of life.

And plants not only breathe the air; they also feed upon it. All living tissues, as we have previously mentioned, contain carbon, and plants, with the assistance of sunlight, and by means of the green substance known as chlorophyll, get hold of the carbon dioxide in the atmosphere, tear the carbon from the oxygen, and use it for building up their living matter, or protoplasm. The enormous coalfields consist of carbon extracted from the air by the ancient forests. Wood contains nearly half its weight of carbon.

Animals, again, get the carbon they require by eating the carbon-containing plants. If there were not carbon dioxide in the air, plants could not get material to make their substance, and animals, in turn, could not get material to make theirs. Of such importance is the gas which we see bubbling in a soda-water bottle!

Not only does the life of man depend on the air, but even if he could live without air, his life would be a much poorer thing; for without oxygen there would be no fire, and without fire man would be little better than a savage. In a fire-mist, probably, man was conceived, and with fire he has blazed his path from savagery to civilisation. Wisely did the Greek myth relate how a god filched fire from heaven; wisely did

the philosopher define man as the fire-making animal. Without air, no fire; without fire, no arts, no trains, no motor-cars, no steamers, no telephones, no telegraphs, no telescopes, no microscopes. To the ardent affinity between oxygen and carbon we owe more than we can possibly calculate.

Further, were the carbon dioxide and the oxygen in the atmosphere not in due proportion, and not diluted with nitrogen, respiration and combustion would be quite impossible. In pure oxygen or pure carbon dioxide we should choke. In pure oxygen a fire could never be extinguished; in pure carbon dioxide it could never be kindled. Even were the atmospheric gases mingled in different proportions, the difference would alter the whole vital aspect of the world.

The Ameliorative Effect of the Atmosphere in All Weathers

Suppose that man could live and flourish without breath and without fire, even still he could not live without air. Except for the air we should be alternately grilled and frozen—grilled all day and frozen all night. The two hundred mile layer of air round the globe acts as a parasol by day and as a blanket by night. It tempers the heat of the sun; it mitigates the cold of the sunless hours. Let us look at these two functions of the atmosphere.

The atmosphere tempers the heat of the sun. The difference between tropical heat and temperate zone heat, between noon-day heat and morning heat, between summer heat and winter heat, is mainly a matter of atmospheric impediment to the passage of the sun's rays. The obliquer the rays the greater depth of atmosphere they have to pass through, and the more their passage is impeded. In the tropics the rays of the sun are more vertical than in the temperate zones, hence the tropics are hotter than the temperate zones. At noon the rays of the sun are more vertical than in the morning, hence the noon is warmer than morning. In summer the rays of the sun are more vertical than in winter, hence summer is warmer than winter. It is mainly a matter of atmospheric interference, though, of course, the more oblique the rays, the less concentrated is the heat where they fall.

The Interception of the Rays of the Sun by the Atmosphere

In the same way as we ascend, and as the layer of air between us and the sun grows thinner, the sun grows more scorching.

When we examine the colours of the visible solar spectrum, we find black lines here and there, indicating that certain rays which started from the sun have been absorbed en route. In the invisible spectrum similar lines indicating absorption appear: there are cold streaks amid the infra-red heat waves, and non-actinic streaks amid the ultra-violet actinic rays. Most of the lacunæ, or vacant places, are due to absorption of rays by the atmosphere of the sun, but others, no doubt, are due to the absorption of the rays by the oxygen, and nitrogen, carbon dioxide, water vapour, and dust of the earth's atmosphere. Tyndall calculated that the atmosphere intercepts about four-tenths of the solar heat during the whole day, and Bunsen and Roscoe calculated that, in passing through the atmosphere, the sun's rays lose about sixty-six per cent. of their chemical potency. Every cloud that passes across the sun demonstrates how the atmosphere mitigates the sun's heat; and every photographer knows how much the chemical potency of light varies with the condition of the atmosphere.

Nay, the blue sky itself testifies to the impediment of the atmosphere, for the blue is due chiefly to the dispersion of blue rays by the particles of dust in the atmosphere. Many of these blue rays eventually reach the earth, but others no doubt are permanently stopped.

What We Should See in the Sky If there Were No Atmosphere

The blue rays, which are at the chemical end of the spectrum, represent little ripples in the ether; and just as little ripples of water may be broken by small stones while big waves roll over them, so these rippling little blue waves of air are stopped, while the larger yellow and red waves mostly roll on. But when the light passes obliquely, and has therefore to pass through a thicker layer of air, not only the blue but also the red rays are broken, as we see in the red of the sunsets. Were it not for the atmosphere we should see a blue sun in a black sky; we should see the stars by day, and we should miss all the glories of the sunset. It is noticeable that at great altitudes the blue sky becomes a darker blue, and some stars become visible by daytime.

If the atmosphere were removed, the sun would be intolerably hot. At an altitude of 11,000 feet water can be boiled by exposing it in a blackened bottle to the sun; and if there were no atmosphere at all the ocean would soon be boiling hot and would all evaporate away; nay, it is possible that even the rocks would melt, realising such a con-

tingency as Burns imagined when he sang:

Till a' the seas gang dry, my dear,
And the rocks melt wi' the sun.

Tremendous would be the heat by day, and equally tremendous, as we shall see, the cold by night, though perhaps on moonlight nights the sunlight reflected from the sun might raise the temperature a little.

But the sun has more than thermal power; it has mysterious chemical power, and possibly electrical and other powers, too. Violet and blue rays hasten the hatching of flies' eggs; they sunburn the skin; they kill many microbes; they combine chlorine and hydrogen into hydrochloric acid; they cause the oxidation of oxalic acid and other substances; they blacken silver salts, and when they fall upon the eyes of animals they cause a quicker absorption of oxygen. These are a few of the chemical things that we know the rays of the sun can do, and no doubt they do many things that we do not know. Certainly they would act more potently were they not enfeebled by the atmosphere. While, if there were no atmosphere, rays that at present do not reach the earth would reach it and produce novel effects.

The atmosphere, then, filters and enfeebles the rays of the sun; and the rays of the sun that now reach us and warm the earth, and make leaves green and cheeks rosy, are *selected* rays. Did all the rays of the sun reach us, the result would be disastrous. More heat, and we might be roasted; more light, and we might be blinded; more chemical rays, and we might be slain like microbes, or completely changed in our mental and physical habits.

So much for the air as a parasol. Let us now regard it in its capacity as a blanket. As we have seen, the air impedes the passage of sun rays to the earth, but even more does it impede the radiation of heat from the earth. During the day, the earth is warmed by the sun; and during the night, when the air is cooler, it tends to radiate away its heat. But the heat radiating away is absorbed by the atmosphere, especially by the aqueous vapour and carbon dioxide in the atmosphere, and is radiated back again.

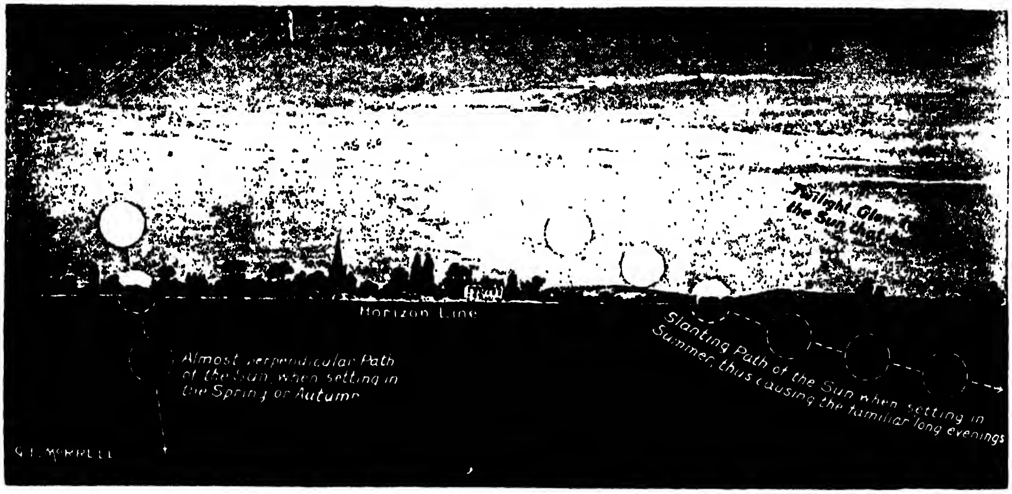
The effect of the aqueous vapour in keeping the earth warm is shown in many ways. It is well known that cloudless nights are much oftener frosty than cloudy nights, and that places with dry climates

WHAT NATURAL SCENERY WOULD BE LIKE IF THERE WERE NO ATMOSPHERE—AN IMAGINARY AFTERNOON SCENE IN THE ISLE OF WIGHT

have a much greater fall of temperature at night than places with moist climates. Thus on the Karroo, in South Africa, where the air is dry, there is a great difference between the day and night temperatures; whereas in Teneriffe, where the air is more humid and where a blanket of cloud gathers round the Peak in the evening, there is only a slight drop of the temperature at night. At high altitudes, also, where the air is dry, there are great diurnal extremes of temperature. At Quito, for instance, which is 9350 feet above sea-level, the daily variation of temperature at some periods of the year is no less than 34° Fahr., and in a balloon at the same height the variation of temperature would be still greater.

It is interesting to note that the aqueous vapour in the air is in a way an automatic regulating apparatus. As the sun's power increases, more water vapour is raised, which at a certain height condenses into cloud and impedes the passage of further heat-rays. As the cold increases, the cloud falls in rain, and the heat-rays have again clear passage.

Great as is the thermal importance of the aqueous vapour, the carbon dioxide in the atmosphere must be considered of almost equal importance. Carbon dioxide is especially opaque to such rays of dark heat as the heated earth radiates towards space. It acts very much like the glass in a hothouse: it transmits the luminous rays of the sun,



WHY TWILIGHT IS LONG IN JUNE AND DECEMBER AND SHORT IN MARCH AND SEPTEMBER

Not only does aqueous vapour prevent the leakage of heat from the earth, by absorbing heat and radiating it back, but it contains great stores of latent heat which are given back if the cold be great enough to condense it. According to Dr. Huggard, every pound of water that is condensed from vapour "liberates heat enough to raise the temperature of more than 58 lb. of lead to its melting point, or to heat and melt more than 58 lb. of lead or 5 lb. of cast iron." And the Rev. Dr. S. Haughton calculates that one gallon of rainfall gives out latent heat sufficient to melt 75 lb. of ice or 45 lb. of cast iron. As vapour contracts and condenses into a cloud, it is an example on a small scale of the contraction and condensation of the original nebula, and the heat given off from the cloud is of the same nature as the heat given off from the contracting sun. Every cloud has a fringe of fire.

but will not allow the dark rays of heat radiated from the heated earth to radiate away again. So successfully and persistently does it oppose radiation that a very small increase or decrease in the carbon dioxide has very large thermal consequences. The atmosphere contains on the average only ·04 per cent. by volume of carbon dioxide, yet even the removal of that small quantity would have serious consequences. According to the calculations of Arrhenius, the removal of the carbon dioxide from the atmosphere would lower the temperature of the earth's surface by about 21° centigrade, and this lowering of the temperature of the crust would diminish the amount of water in the atmosphere, and thus lead to a further almost equally great fall of temperature.

Arrhenius also calculates that any doubling of the percentage of carbon dioxide in the air would raise the tem-

perature of the earth's surface by 4° centigrade; and that if the carbon dioxide were increased fourfold, the temperature would rise by 8° centigrade. Further, a diminution of the carbonic acid percentage would accentuate the temperature differences between the different portions of the earth, while an increase in this percentage would tend to equalise the temperature.

Of such thermal value, then, are aqueous vapour and carbon dioxide in retaining the heat that the sun supplies to the earth.

Suppose, then, that all the atmosphere were suddenly removed one morning, what would happen? During the day, as we have seen, the unimpeded heat-rays of the sun would boil away the sea and fill the atmospheric zone with an enormous volume of water vapour, but the moment the sun fell the upper margins of this layer of water vapour would be exposed to the terrible cold of outer space—a cold estimated at −239° Fahr.—and the instantaneous result would be tremendous falls of hail and snow, until the whole earth became a white, frozen ball of ice and snow. All night long the snow and hail would fall, covering hill and valley many feet deep, and the morning sun would rise upon a white, Arctic world. Blazing on the snow and ice, the sun would melt them everywhere; there would be a thaw, but probably the heat of the sun would not be sufficient to melt and evaporate all the snow and ice, and the world would assume a permanently frozen aspect, and probably by day there would be water actually boiling in icy kettles.

Though the earth has always had an atmosphere, it is possible that some of its glacial and tropical periods were due to alterations in the quality and quantity of the atmosphere.

Besides aqueous vapour and carbon dioxide, the dust affects the passage of the sun's and earth's radiations; and in the great volcanic eras, and in the eras of mighty tempests, the dust may have played an important part in modifying the temperature of the earth's surface. These are, perhaps, the most sensational parts the atmosphere plays, but it plays many other parts. It actually increases the length of the day by refracting the rays of the setting sun, so that it still appears above the horizon after it has actually set. On the equator the period of sunlight is increased in this way by only four minutes, but in the higher latitudes the total increase of sunshine thus obtained amounts to hours. It is quite a fashionable thing nowadays to go to the Land of the Midnight Sun; but the midnight sun in such a case is really an optical delusion, for though it *seems* to keep above the horizon, it actually sinks below it.

A DIAGRAM EXPLAINING WHY WE SEE THE SUN AFTER IT HAS SET

Physiologically, the air is indispensable. Not only is it a *sine qua non* of respiration, and thus of all vital processes, but it is the medium of sound-waves. Without air there would be dead, appalling, universal silence. The surges would break silently on the sands; the lightning would flash without thunder; Niagara would fall over its precipices without a sound.

In æsthetic ways, too, air plays a part. It is air-waves that make a Beethoven symphony; it is air that gives us rainbows and Northern Lights; it is air, or, at least

the dust in the air, that gives us the blue sky and the gorgeous sunset hues; and it is also air-dust that gives a softness to the lights, and shades, and lines of the world. Without atmosphere, all lines would be hard, and all shadows black and uncompromising.

How Comes It that the Earth has Exactly the Air It Needs?

In subtler ways, too, the atmosphere does many unsuspected things. Who would think that it is atmospheric pressure that keeps the heads of our thigh-bones in their sockets? Lift the weight of the atmosphere, and we should all wobble about with dislocated thighs. In brief, then, even supposing that we could live without atmosphere, we should be lame, and blind, and deaf, living in a world without chiaroscuro—a world with a blue sun shining in a black, starry sky—a world alternately frozen and roasted, with pools of boiling water in pot-holes of ice.

It is probable that only the earth has this wonderful rind or fluff of gases. Certainly only the earth has that special combination of gases that we know as the air. Marvellous it is, surely, that these few gases should have such momentous consequences, and that they should be found just where they are wanted, and apparently in just the quantities required. The earth might quite well have lain naked and bare-faced to the stars, and then what an abortion it would have been! Or it might have had a surplus only of oxygen, or only of nitrogen, or only of argon, or only of carbon dioxide, and then where would we have been? Well may we wonder how the gases come to be there so opportunely, well may we inquire into their origin and history.

Are the Atmospheric Gases By-Products Left Over When the Rocks Were Made?

Where did they come from? The most obvious answer is that they are the last uncondensed and uncombined gases of the gases of the original nebula. In so far as the earth has this fringe of gases, in so far it is still in a nebular condition. At first, according to the nebular theory, the earth was all gases together, but as its heat radiated away the gases became liquids, and the liquids solid. The iron, the silicon, and other elements solidified into the rocks, the water vapour condensed into the oceans, and ultimately all the gases were converted into liquids or solids, except the gases now in the air, and perhaps some gases at the earth's core. On this theory, "we must regard the atmosphere of any planet at any time as the mere residuum which has been left after all possible combination has taken place," and oxygen, nitrogen, carbon dioxide, and water vapour are by-products left over when the rocks were made.

Is this a likely theory? At first sight it seems very likely, and, indeed, if we are to accept the nebular hypothesis, this explanation of the atmosphere almost necessarily follows, but when we look into the matter there are many difficulties.

It is quite likely that nitrogen might have remained unwedded; it is not a marrying element, it has a sluggish, unsociable disposition. But oxygen is amorous and sociable; it links arms on every chance; and there are plenty of substances in the earth's crust quite ready to wed it. How, then, did oxygen remain out in the cold at the fiery time when weddings were so much the fashion?

Difficulties of the Theory that Air is Gases Left Over from Solid Combinations

Again, on this residual theory all the water in the sea, and all the carbon dioxide and oxygen in the earth's crust supplied to the crust by the atmosphere, must at one time have been in the atmosphere, and the water vapour and carbon dioxide still in the air are simply a remnant of the original stock. But this would mean that the atmosphere was once of most tremendous extent. If we were to restore to the atmosphere all the carbon dioxide in the carbonates of the earth's crust, we should have an atmosphere of carbon dioxide more than two hundred times the volume of the present atmosphere. In the lime strata of the Carboniferous epoch alone there is imprisoned six times as much carbon dioxide as is present nowadays in the air. Huge amounts of oxygen, too, might be recovered from the oxidised rocks in the earth's crust.

Accordingly, if the atmosphere was a residuum, it must have been a tremendously voluminous residuum—so voluminous that gravity could not possibly have held it. Gravity can just hold with difficulty the present atmosphere, and any additional gases given to the atmosphere would fly away. We cannot, therefore, believe that all the gases that circle and that have circled the world were left over as one immense atmosphere from the primæval fire-mist. In fact, the atmosphere does not seem to fit in to the nebular hypothesis.

Let us see what the meteoritic hypothesis can do. According to this theory, as we have seen, the earth grew by an agglomeration of meteoric particles which gathered together under the influence of gravity, and were

THE AURORA BOREALIS, THE BEAUTIFUL NORTHERN LIGHTS MADE VISIBLE BY THE PRESENCE OF DUST IN THE ATMOSPHERE

heated and melted by the heat generated by impact and contraction. At first the globe would be small; and even if there were molecules flying about, it would not have enough gravitative force to gather them around it into an atmosphere, but after the earth attained to about the size of the moon it would begin to collect the flying gases. The first gas captured would be carbon dioxide, since this gas has the slowest and heaviest molecules; then would come oxygen, then nitrogen, and, lastly, water vapour.

But even if we accept this theory of the capture of gases it does not get us out of the difficulty, for the earth has not gravitative force sufficient to capture *all* the aqueous vapour now condensed in the sea, and *all* the carbon and oxygen now in the earth's crust, but evidently formerly in the atmosphere. How are we to get over this difficulty?

The Likelihood that the Gases of the Air Have Come Out of the Earth

There seems only one way of surmounting the difficulty and of explaining such a large volume of atmospheric gases, and that is by supposing that the greater part of the atmosphere and of the aqueous vapour now in the sea were originally built into the earth's crust. We find that meteoric stones always contain gases in their pores, and if the earth were built up of such meteoric material it must have contained the meteoric gases. Again, we find that lavas and molten liquid, however hot, may hold gases in solution, and that if they solidify under pressure they will retain the gases in their substance, much as a bottle of frozen champagne would retain the gas in the ice. The gases found in meteoric stones are chiefly hydrogen, carbon dioxide, carbon monoxide, marsh gas, and nitrogen. And supposing these same gases were enclosed in the solidifying rocks, the hydrogen would probably take oxygen from the ferric oxide so common in the earth, and thus form water. It is probable that the carbon monoxide would change into carbon dioxide, and that the marsh gas would disappear. We would thus have left three of the chief gases of the atmosphere—nitrogen, carbon dioxide, and water vapour.

How about oxygen? Oxygen might be produced under certain conditions by the ferric oxide. Thus we should have all the gases of the atmosphere in the bowels of the earth either shut into the solidified rock or in solution in molten masses. Granted that they were there, it is easy to see how they could escape to the surface through volcanoes and in other ways, and thus form the atmosphere. On this hypothesis, *all* the atmospheric gases would not be in evidence *at once;* they would escape to the surface, and enter into combination in the crust *pari passu.* As quickly, for instance, as the carbon dioxide was buried in the earth as coal it would be replaced by volcanoes..

Volcanoes as the Source of One Constituent of the Air

A certain amount, then, of the atmospheric gases may have been captured from space, or a certain amount may have been left over from the rocky material of the world, but the greater bulk of the gas must have been extracted from the crust itself, to enter again into solid combinations with its surface layer.

Probably all the carbon dioxide was belched forth by volcanoes. Even in the present day of comparative volcanic quietude vast volumes of carbon dioxide are given forth by volcanoes. According to Boussingault, the volcano of Cotopaxi gives off as much carbon dioxide as the whole city of Paris, and a few such volcanoes blazing for a few hundred thousand years would eventually provide the ·04 per cent. of carbon-dioxide in the atmosphere.

Probably Changes in the Atmosphere and in the Accompanying Forms of Animal Life

It is probable, indeed, that at first the atmosphere of the earth consisted almost of carbon dioxide and nitrogen, and it is quite likely that oxygen was added to the air by the vital activities of the first green plants, and that this was its main source. In this primitive atmosphere of carbon dioxide green plants would flourish exceedingly; and when we consider that there must have been tropical heat and abundant aqueous vapour, we can well understand the luxuriance of the vegetation in the Carboniferous period. When the primæval jungles had manufactured enough oxygen to supply large animals, large animals began to appear. At first, naturally, only animals with sluggish natures could live, and no doubt the reptiles of the Palæozoic and Mesozoic eras were qualified to live in a muggy, carbon-dioxide-laden atmosphere, but as the oxygen accumulated and the carbon dioxide was locked up, the atmosphere became more fitted for active animals, and more active animals, birds, and mammals, appeared; for, after all, the processes of life are mainly a matter of oxidation. When we look at the moon we find that

it has been the seat of furious volcanic action, and probably, if it had only been big enough to hold back the volcanic gases, it, too, might have acquired an ocean, and animals and plants. Without an atmosphere our world would be dead as the moon and almost as dry. It is quite conceivable that some of the volcanic gases of the moon were captured by the earth.

Seeing that the atmosphere has probably altered in the past, it is natural to inquire whether it is still altering, and whether there is likely to be any further change in its size or in the proportion of its gases. On the face of the earth to-day there is springs and fires throw an enormous amount of carbon dioxide into the air. We know, on the other hand, that a single acre of green ground is sufficient to remove the carbon dioxide discharged by twelve or thirteen persons, and to restore to the atmosphere the oxygen the persons retain. Whether, however, plant life is sufficient to break up *all* the carbon dioxide annually added to the atmosphere is a moot question. If the carbon dioxide be actually increasing, it might be a serious matter for the animals of the world; but the more carbon dioxide the air contains, the more will green plants consume, and that must do something to

A VISTA OF THE ALPS, WHERE THE ATMOSPHERE IS RARE AND CLEAR

This photograph, by Mr. Donald McLeish, was taken from the summit of Mount Pelvoux, 12,973 feet high.

great gaseous activity. Men, beasts, plants, volcanoes, fires, are all giving and taking gases. Is the proportion of carbon dioxide increasing or decreasing? It is a question of momentous importance to the whole human race, for the evolution of man may depend on the stimulus of a little more or less oxygen. If the oxygen be reduced, man may become as lethargic as a lizard; and if it be increased, all his faculties may be quickened proportionately.

The question cannot be confidently answered; we have not enough data. We know that men, and animals, and decay in vegetation, and volcanoes, and mineral

counteract any excessive production of carbon dioxide. But the great regulator of the amount of carbon dioxide in the air is the sea. The sea contains twenty-seven times as much carbon dioxide as the air. If a certain additional amount of carbon dioxide is given to the air, a large proportion of it is at once seized by the sea. For this reason it would require an enormous surplus production of carbon dioxide to produce any marked effect on the earth's atmosphere; and altogether we may be confident that green plants and the blue sea will protect us from any deleterious increase of carbon dioxide.

INTERIOR OF A NEST OF ACTIVE WASPS

The wasp furnishes an interesting example of social organisation, each individual in the nest working for the general good. In this photograph, by Mr. J. J. Ward, the wasps seen on the upper tiers of the comb are workers. On the lower tier are two young queens and a male bee.

LIFE'S CHOICE OF THE BEST

Spontaneous Favouritism for Whatever Serves the Individual Good or the Common Weal

HAS NATURE A SENSE OF MORALITY?

THE idea that natural selection has created the forms and powers of the living world is seen to be absurd. That is clear gain for our century, compared with the latter half of the nineteenth, when the great majority of those who thought at all saw no way out of the mechanical theory which, we now see, explains why what is not is not, but does not explain how what is came to be. Judged on the plane of philosophy, natural selection is condemned; the problem of *origin*, which it purported to answer, is not even alluded to in the theory of Darwin and Dr. Wallace.

And now the way is clear for our study of natural selection in general, and its significance in the study of life. Over-production, heredity, and variation are facts of the living world, and therefore, as we have seen, natural selection must necessarily occur. But further, we need recognise only heredity and variation in order to see that many other kinds of selection, obviously possible, may produce notable results so long as variations occur; selection chooses among them, and heredity perpetuates them.

When the selection is simply the destruction of those who are least able to survive in the conditions, we call it "natural selection," and the phrase is always misused when it is applied in any other way. Yet natural selection may be infinitely various in its consequences, according to the particular conditions which preside over it, and many a volume has been written on that question alone. And when that subject is quite threshed out, as it can never be, we realise that all sorts of other selective agencies are possible, each capable of affecting the future composition of a species in any degree.

Thus, as Darwin taught, individuals may choose one another as mates, or individuals of the same sex may fight one another for the possession of a member of the opposite sex. Plainly selection is at work in such cases. It is not natural selection; it has nothing to do with available food-supply, nor the struggle for life, and it has or may have special consequences of its own. Darwin gave it the name of sexual selection.

Again, the fertility of individuals, plants, or animals may differ. Any two of them may be equal, perhaps, in the struggle for life, or one of them may barely survive in the struggle; but that one may be fertile, and the individual which, as an individual, is an easy winner in the struggle for life may be infertile or scarcely fertile. The individual may thus be selected by natural selection, only to be condemned by what may be called reproductive selection; and we can readily see how the action of this mode of selection may affect the composition and destiny of a species.

Yet again, man may so modify the conditions of his own life, or those of the life of any living species he takes an interest in, that those who would have survived are rejected, and vice versâ. This may often occur in artificial selection, as practised by the human breeder, of pigs or bees or peas, or anything else. But, further, man may quite unknowingly and unintentionally subvert the normal conditions of selection in his own species, so that the survivors are just those who, in natural conditions, would not have survived. This is, by a quibble—that everything is Nature—natural selection still; but we may quite usefully recognise its peculiarity, from our point of view, and call it *un*natural or reversed selection. And, on the other hand, the Eugenists are now setting out to practise a form of selection, for ideal ends established by themselves, quite apart from the automatic and impartial attitude of Nature, and this has been called human or eugenic selection.

And, again, when Professor Weismann,

some years ago, was very hard pressed to explain certain facts on his theory of the germ-plasm, he invented what he called germinal selection, a kind of struggle for life between germ-cells, or between different constituents of the "germ-plasm" in the formation of germ-cells from it. Not much is heard of germinal selection nowadays, but the theory is conceivable, and its invention and its inventor will always be part of the history of the science of life.

All the forms of selection hitherto named have dealt with individuals, but there are other possibilities. No theory of selection that simply had regard to the life of the individual could explain the evolution of, say, the breast of the mammalian mother, or of any other structure which serves its individual possessor not at all. There has been not merely the "struggle for life," with what we call natural selection as its result, but also "a struggle for the life of others," with the result which we may call altruistic selection—*i.e.*, other-ish selection. Here the individual is formed and chosen not for itself alone, any more than, say, the hand or the heart is formed for itself alone. The individual is shaped and chosen as an organ of the race. Here is a great idea, not unseen by Darwin himself, which it was left to Henry Drummond to state as it deserved to be stated.

And, lastly, we learn from a multitude of instances that what is really, in a sense, a form of natural selection—as altruistic selection is too, no doubt—occurs, not with reference to individuals, but with reference to societies. In societies of insects or of men, the unit of selection, the unit judged and taken or left, may be not the individual, any more than any particular organ of the individual, by itself, but the society or community *as a whole*. Thus a nation may be selected and another rejected, or a society of bees, whose social character is high, as against another swarm, in which the bees are comparatively improvident, for insect societies vary just like human societies.

In the case of mankind, innumerable social influences—such as, say, the type of marriage, whether monogamous or polygamous—may determine the "viability" or the "survival-value" of the society. And thus it may be chosen, or extinguished, not in reference to its individuals as individuals, but as a social whole. Where the unit of selection is thus a society, we must plainly call the process social selection.

That completes our first survey of the subject, and we begin to see its interest and difficulty and complexity. For within the society upon which social selection is being practised, in its struggle for life with other societies, there are also at work natural selection, and sexual selection, and the other forms of selection, which may be mutually complementary, or merely supplementary, or, on the other hand, may neutralise or antagonise one another. And at every change in the environment, whether of climate or diet, or the presence or absence of other species, whether the introduction of new ideas, or new inventions, the balance and interplay of all these modes of selection is altered—perhaps radically and momentously, by a change in conditions apparently so trivial that no one can even name it. No wonder that the interpretation of the history of man, his races and nations and civilisations, is as difficult as past attempts at such interpretations demonstrate!

Let us put our forms of selection together in an ordered list, and then attempt to state the main propositions which must form the basis of all future thinking upon this subject. Here is the list, and though it might be added to if we chose, it includes all the important forms of selection

GROUP I.

1. Natural Selection.
2. Sexual Selection.
3. Reproductive Selection.
4. Germinal Selection.

GROUP II.

1. Altruistic Selection.
2. Social Selection.
3. Artificial Selection.
4. Reversed or Dysgenic Selection.
5. Eugenic Selection.

The writer has made an attempt, in the foregoing list, to include the typical and admitted forms of selection, together with others which may some day be discarded, and to group them, for convenience of study, into a first group where the unit of selection is the individual, and a second group where the unit is more than an individual, or where the selective agent is itself a group of individuals. It is not pretended that the classification is perfect, but it may be offered as a tentative attempt. Let us now review these forms of selection, already briefly defined and described, trying to grasp the essentials of each, if possible.

But, first, there is one general question which must be disposed of. Man is a moral being, and has a moral point of view. If

the forms of selection are the judges of the forms of life, man is himself the judge of the forms of selection. So he must be; and the first condition of just judgment is to understand the facts of the case; above all, the fact that selection is not, in itself, moral or immoral. Thus natural selection is the survival of the fittest, and though the fittest may be the best, as man judges, so may they just as possibly be the worst. It all depends upon the conditions. The conditions are the real determiners, for they decide what the selective process shall result in. It is merely the machinery.

Natural Selection a Fight to Show Fitness Between Men and Disease or Man and Man

The name of "survival-value" may be given to the quality or combination of qualities in virtue of which individuals, species, societies survive. Thus the murderous sting of the worker-bee, the bosom of the mammalian mother, the "toxin" of the microbe of consumption, alike are instances of "survival-value," the first under the heading of social selection, for it helps not the bee but the bee-hive; the second under the heading of altruistic selection, and the third under the heading of natural selection.

Plainly our moral judgment upon selective processes, our approval or disapproval, must depend not merely upon the particular type of process, but upon its results.

GROUP I.

I. NATURAL SELECTION

This has already been discussed, and only one point needs adding. It is that natural selection, in the case of man, notably takes the form of a struggle for the life of the individual, and for the life of the human race as a whole, against the humble forms of life which depend, for their existence, upon the production of disease in man. This aspect of natural selection, dealing as it does with matters which come so near to "men's business and bosoms," requires and will receive special discussion according to the various species—tubercle bacillus, malaria parasite, and so forth—with whom the fight is waged.

The Fight is Not to be Fought That it May Weed-out the Unfit

There is, however, a second aspect to this contest, which has been very largely discussed. Not only is the selective struggle between man and his enemy, but it is also between the individual man who resists more strongly and him who resists less so. The selective process may act inside the species. Exposure to, say, the tubercle bacillus may mean that the most susceptible members of successive generations of man are weeded out, they and their possibility of producing offspring like them, so that a population will be evolved which is immune to the attacks of the bacillus, and thus the disease will be conquered.

The same argument has been applied to the use of alcohol, the assertion being that we must allow "natural selection"—as these writers fantastically call the influence of the slum or of the gin-palace—to weed out the susceptible, until we produce a race the members of which are proof against the dangers of alcohol.

This line of argument is here noted, as it must be, on account of the wide credence which it has gained among the half-informed, and because one or two distinguished writers, now belonging, however, rather to the past than the present, have formally urged the theory of natural selection against all attempts to fight alcoholism, tuberculosis, and similar enemies of mankind. Elsewhere in the course of this work it will be shown in what comprehensive detail the facts recorded by the first-hand science of experiment and observation are in direct opposition to these speculators.

Darwin's Theory that Sexual Selection Adds the Beautiful to the Useful

2. *Sexual Selection.* The theory of sexual selection was set forth at length by Darwin, in his second book, "The Descent of Man," with great wealth of observation and argument. The theory was well worth framing, and has immensely stimulated thought and research during the forty years since its publication, but no modern biologist ranks it as high as popular opinion still does. Darwin's theory was practically an application to the animal world of arguments from the case of man, just as his theory of natural selection was an application to the living world in general of the idea of artificial selection as practised by man.

The theory was introduced by Darwin as a supplement and complement to the theory of natural selection. If natural selection were universal and constant in its action, and if nothing else were at work, every feature and characteristic of every living being ought to be useful. If it has been made by the struggle for life, it must have some "survival value." We can thus understand how natural selection would favour the feathers and the eyes of the bird, by which it is helped to fly and mark its prey. But why should those

feathers be not only useful but often beautiful? Nay, more, why should those feathers be sometimes so extravagantly beautiful, so large and unwieldy, that, instead of favouring the possessor, they must gravely handicap him in the struggle for life? On all hands, but perhaps chiefly among the birds, we find features which natural selection cannot explain, and which natural rejection—to call it what it really is—should have rejected. But there they are. Darwin's theory of sexual selection came to the rescue.

The Failure of Darwin's Illustrations to Apply to Half the World

He supposed that the wonderful markings and plumage, or the ravishing voices, of male birds are the result of selection by the females, who choose the suitor with the finest suit, or the serenader with the sweetest serenade. Such a process, assuming any constant standard of taste among the female birds, would plainly lead to the accentuation in the race of those characteristics which they persistently selected, and which would tend to be transmitted, and thus fixed in the race, by the mates they chose. Doubtless sexual selection may be imagined to take other forms, as when a number of males, say bulls, fight for the possession of a female, and thus pugnacity and strength and persistence are selected, and tend to be fixed in the race.

There can be no doubt at all that time has not been kind to this famous theory of Darwin. It cannot apply to plants, yet plants may occasionally, or perhaps rather oftener, vie with the beauty of animals. As an explanation of the evolution of features not purely useful and therefore inexplicable by natural selection sexual selection is thus irrelevant to half the world of life at the very least; and whatever explanation serves for the beauty, the not useful beauty, the "art for art's sake," of plants may serve for animals also.

The Later Experiments that do not Reinforce, but Weaken, Darwin's Argument

Again, many features not useful, often very beautiful, and sometimes evidently disadvantageous, are found in living species where sexual selection is impossible, or where reproduction is asexual. Yet again, we lack evidence to show that female birds possess the mental and æsthetic development and fastidious discrimination which the theory of sexual selection involves. And, lastly, there is the most fatal objection that, taking the world of life as a whole, the rule is that all adults become parents, whereas sexual selection can only be operative if certain kinds of individuals are chosen for parenthood and others are rejected. If there is no selection at all, since all become parents, there is no "sexual selection." To this brief summary of negative criticism may be appended the further observation that, in the last few years, the experimental breeding carried out by the Mendelians has gone a very long way to demonstrate how the colour and plumage, for instance, of birds is transmitted, and what laws govern the formation of such characteristics in the first place. The positive facts thus obtained are quite incompatible with the theory of sexual selection, and require a wholly different interpretation.

We hinted that probably Darwin was led to his theory of sexual selection through argument by analogy from the case of mankind. That should remind us that to reject the theory of sexual selection, at any rate as of substantial importance in the evolution of the animal world, is by no means to deny its importance for mankind. On the contrary, every year's inquiry strengthens the view that sexual selection must be of the most tremendous importance in the case of mankind. Men and women *do* have the likes and dislikes with which Darwin credited birds. Only a proportion of men and women become parents, and there are demonstrable differences, on the average, between the parents and the non-parents.

The Sexual Selection Practised by Mankind Inapplicable to the Rest of the Animal World

Sexual selection in mankind, as regards beauty, for instance, is unquestionable, and must constantly tend to prevent a lowering of the standard of facial beauty. This selection is most conspicuously practised by men, exactly inverting what Darwin supposed in the case of birds, and the contrast is completed when we observe that woman steals and dons the plumage of the male bird in order to please the male of her species. Careful and prolonged inquiry by Professor Karl Pearson, now several years ago, has seemed to show, further, that married couples, on the average, notably resemble one another, in eye-colour, stature, and many other characteristics. This suggests not only that sexual selection exists among mankind, but that the tendency is for us to select our like—not our opposites, as the popular theory supposes.

To this principle, the mating of like with like, Professor Karl Pearson has given the convenient name of homogamy—*i.e.*, like-marriage; and it is one of the many reasons, derived from modern research, why sexual

selection increases its importance in the estimate of modern science, so far as man is concerned; while its inapplicability to the animal world, in any large degree, becomes more and more evident. Here we leave the theory, then, merely noting that, while it almost passes out of biology, the science of life in general, it must be of vital importance for the new science of eugenics.

The Limitations that Apply both to Natural and Sexual Selec.ion

3. *Reproductive Selection.* We begin to realise that the evolution of a species does not depend, in the last resort, either upon natural selection or upon sexual selection, and cannot do so. Natural selection selects or rejects individuals, and thus largely explains the presence and the absence, in any adult generation, of the more fit and the less fit, respectively, from among those who were born to bid for life in that generation. But while natural selection explains, obviously, why some live and others die, it can have no bearing upon the race, it cannot affect the evolution of a species, unless we assume that the survivors become parents. If they do not become parents their personal selection and survival have no bearing on the future composition and characteristics of the species. Just so, sexual selection, as such, merely explains who mate and who do not mate, as natural selection explains who survive and who do not survive. But sexual selection obviously has no influence upon evolution of the race unless we assume that mating means parenthood. More than that, the mating which results from sexual selection must be superior in fertility to that which does not, if evolution is to be affected. If the mating which results from sexual selection is habitually sterile, or produces, say, only a few offspring, while the mating of the individuals who are, so to say, "left over," is more fertile, then the selective mating may be impotent as regards evolution.

The Course of Evolution Determined Neither by Selection nor Mating, but by Parenthood

Plainly, then, if any process of selection is to affect the race, and so explain or condition the course of its evolution, it must result in offspring. And thus we see that the whole theory of natural selection, with that of sexual selection, assumes a superior fertility on the part of the selected; and we begin to appreciate the idea of reproductive selection. Not survival, not mating, but parenthood determines the course of evolution. From and by what individuals, having what characteristics, *however selected*, is the species recruited? That is the whole question so far as its evolution by selection is concerned.

The comparative study of fertility rates thus becomes of immense biological importance. We require to study and number and compare the seeds or fruits or embryos —the offspring, in short—of all manner of animals and plants, so as to ascertain the types of individuals that are most fertile, which is a huge task in itself, and then to ascertain the particular types of matings that are most fertile. The last word is, necessarily, always with fertility or reproductive selection. It is not enough for Nature, or the gardener, or the Eugenist to select the kinds of individuals that are best adapted, or most beautiful, or most worthy. That is the first step, but it leads nowhere, as regards the making or modification of any species, unless the individuals selected are fertile—nay, more, unless their fertility be so great as to overwhelm that of the unselected stocks with which they may be set in competition.

Fertility the Prime Consideration in Setting Up the Future Standard of the Race

The importance of these questions has only lately begun to be seen, but it is evident enough when once it is stated. In a word, any and every kind of selection that occurs in the living world must be compatible with fertility, and must maintain its compatibility with fertility if it is to affect evolution in any positive direction at all.

4. *Germinal Selection.* This theory of Weismann's belongs, as we have said, to the history of biology, and must be named, but no more is now necessary. We proceed to the second of the two groups in which the forms of selection may be arranged.

GROUP II.

ALTRUISTIC SELECTION

The virtues of clear thinking, accurate naming, and lucid analysis never fail to proclaim themselves in the long run. The controversy that began with the publication of the "Origin of Species" did not conduce to these most desirable processes, never more urgently required than then. Not until many years had passed was it possible for a thinker here, and another there, quietly to survey the facts and weigh the new ideas, without any bias at all. Meanwhile there appeared the most horrible phenomenon in the history of human thought, which based upon the theory of natural selection a declaration that mercy and love and pity are "the morality of

slaves;" that only the great principle of "each for himself, and the devil take the hindmost"—a perfectly accurate paraphrase of natural selection—can exalt a race, and that the final verdict of knowledge had gone forth to this foul effect. Such, in its naked horror, is the essential teaching (together with much that is fine and precious) of Nietzsche, and its substance was none other than this: that in order to become Superman, man must become a devil.

Darwin's Theories Modified by the Ascent of Man Insisted on by Drummond

There is nothing in the history of thought that resembles this ghastly application of Darwinism; and little more ironical than that it should have involved the name and the theory of the patient thinker, who hated fighting, and controversy, and the public platform, and loved his garden and his home and his children, and who expressly repudiated, in the "Ascent of Man," that Nietzschean application of his views which has lately appeared again in the teaching of the "better dead" school of Eugenists.

The answer to this terrible creed, which blasphemes Nature, and denies and insults the natural structure of every maternal bosom in the world, was magnificently stated by the late Professor Henry Drummond, in 1894, in his "Ascent of Man." Written as it was with a confessedly religious intent, and by one whose first-hand acquaintance with the subject was small, Drummond's book received little acknowledgment from men of science, whose experiences in this direction had perhaps scarcely been encouraging. The book was before its time, as we may quickly perceive if we look at the grotesquely materialistic literature which passed for the best and most advanced biological thought of the decade before last. All that kind of thing has died a natural death, though there is an occasional attempt to galvanise its corpse; and we may begin to see how scientific, in substance, was Drummond's contribution to the theory of organic evolution.

The Struggle for Life Qualified by the Struggle for the Life of Others

The "struggle for life," which was all that the smaller followers of Darwin could see, does include, and is constantly transcended by, what Drummond accurately described as the struggle for the life of others. Far more than half the facts of the living world come indisputably under this head, if we will only look at them. The very name of the mammalia, the highest family of animals, at the very head of which man himself stands, gives the lie to Nietzscheanism, and justifies the teaching of Drummond.

The struggle for the life of others, more particularly parental, and still more particularly maternal, may doubtless be included under natural selection, from one point of view. If a mother's love, to choose its supreme example, has "survival-value"—for her offspring—they will be "fitter," thanks to her. Yet only stupidity or bias can fail to see the measureless moral and practical distinction between the struggle and the selection, thus effected, and the typical struggle for life. In this new case, one individual struggles for the life of another, and the other survives, not in virtue of its own merit, but because another has struggled, sacrificed, possibly died for it. The facts may sound sentimental, or may be stated mawkishly or cantingly, but they are just as much facts, say, of the tigress and her whelps, as are her terrible teeth and claws; and their evolutionary interpretation and their evolutionary consequences are obvious and unquestionable.

Care for Others a Law of Nature that Asserts the Morality of Nature

The materialists had tried to pitchfork morality out of Nature, by the theory of selection and the struggle for life; and the issue of the argument, on the ground chosen by them, and waged by their own weapons, has been to demonstrate and establish morality securely in the heart of Nature, from which no "higher criticism" of ancient literature, nor any shock of other discovery, can ever dislodge it. We find that altruism is a law of Nature. Morality, this absurd invention of the priests, say the Nietzscheans, interferes most seriously with the operation of natural selection, which is the only means of giving us the "Superman." To which the reply is that natural selection, in the particular form of it which can only be called altruistic selection, selects morality. It selects whatever serves life, such as jaws and claws; but as love serves life supremely, and serves the highest forms of life the most, natural selection has had no choice but to select love, and to reject the loveless, also. Men ask the origin of good and evil; in this double method, the struggle for life (the life of self), and the struggle for the life of others, we see the biological statement of the answer to that old question. But all this is a matter so momentous, for science and for religion, that we can do no more than thus introduce it now.

2. *Social Selection.* Mr. Benjamin Kidd has done good service to the theory of selec-

ion by showing that, among the higher types of life in especial, the unit selected, as having survival-value, is not the individual at all, but some group, larger or smaller, of individuals who form an interdependent whole, "fit" or "unfit," as the case may be.

We can readily see how complete is the transition from natural selection, "each for himself," through the rudest and most transient forms of family life, involving, at least for short periods, what we have called altruistic selection; thence through the selection, as entire units, of large patriarchal families, if it be man we are considering, or of social groups among the lower animals, up to the cases where entire societies form units, and struggle for life among themselves, apart from and without any immediate dependence upon the individual forms

our list, and are distinguished as being set in motion by man. "Artificial selection" nowadays includes not only the art of the gardener, the agriculturist, the stock-raiser, and so on, but also the experimental breeding practised by Mendelians and others for the gaining of knowledge only. One point alone needs mention under this head. It is that the methods of artificial selection, when deliberately employed, along the lines of natural selection, with the object of trying to produce those changes in the form of species with which natural selection is credited, *always fail.* Such experiments begin as if they were going to succeed, but a point is soon reached when the steady selection of individuals that vary in the desired direction fails to advance the race any further along it. These experiments

MORALITY A LAW IN NATURE—GEESE PROTECTING A BROOD OF GOSLINGS FROM DANGER

of struggle and selection that are taking place within them. We may begin to imagine the significance of social selection if we consider a struggle, perhaps in war, between a highly organised nation, whose individuals may be, as individuals, mediocre, and another made of fine individuals, but not united into a strong social unit. The verdict will be given in terms not of individual but of social selection, even though the result may be that inferior individuals survive. Thus a civilised but degenerate race may conquer in war another nation whose members are not degenerate, but who have not constructed such "social" "civilisation" as results in a standing army, torpedoes, or such-like engines of progress.

3. *Artificial Selection.* We come now to the three forms of selection that conclude

markedly contrast, by their failure, with the success in the formation and fixation of new types which follows artificial selection upon Mendelian lines, as we shall see.

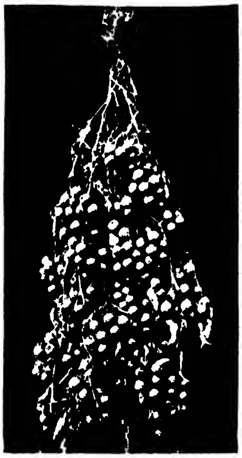
4. "*Reversed*" or "*Unnatural*" *Selection* is frequently practised by man upon himself. It could doubtless be practised also upon other forms of life, but as there would be no possible object in such a process, man naturally avoids breeding from the worst or least desirable, except in his own case. To this process the name of Dysgenic Selection has been given, to contrast with

5. *Eugenic Selection*, which is discussed in another part of this work.

Such, in outline, is the modern fruit of the idea of selection which Darwin and Dr. Wallace introduced into the science of life more than half a century ago.

THE DEVELOPMENT OF THE VEGETABLE

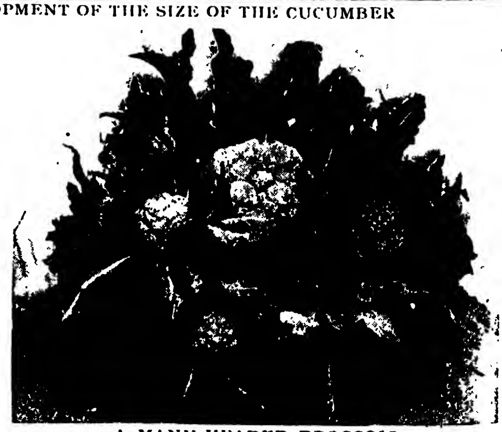
THE SUCCESSFUL PRODUCTION OF SPROUTS ON THE STALK OF SCOTCH CURLY KALE



YELLOW TOMATOES

THE DEVELOPMENT OF THE SIZE OF THE CUCUMBER

THE LITTLE-KNOWN KOHL RABI



A MANY-HEADED BROCCOLI

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MAN'S "CREATION" OF CROPS

Amazing Improvement of Grain, Fruit, and Flowers by Human Intelligence in Crossing Varieties

THE NEW REIGN OF THE SEEDSMAN

Man cannot create in the real sense, but every year are seen new and startling examples of his power to use and to develop the forces and the living things of nature. His control over electricity, the most wonderful and mysterious of the forces, is not more strange than his control over the making, or, as it is often called, the "creation," of plants. During this century we have more and stranger reports of the creation of plants than ever before. We have heard of pipless oranges, stoneless plums, and coreless apples; of plums as big as lemons, of strawberries fruiting in November, of celery that bleaches itself, of wheat that no disease can touch, of roots carrying sugar up to a quarter of their weight, of everlasting clovers, and vetches that may be reaped four times a year, of oats with a thousand berries to the one straw.

We have heard also of cows giving 1500 gallons of milk in the year, of sheep that bear four lambs, of cattle and pigs that come to full growth within a year or so. Some of these reports are true, some are much exaggerated; but they all show how men all over the world are striving to improve, if not to create. Everyone should know in some degree how far it is possible to make new plants, and to keep them true to the newly created nature.

There are three ways of making better, and in some degree new, plants. The first may be called Darwin's way, though it was the way of many others who lived long ago. It is the principle of selection. You continually select the best plants or those which have some peculiarity that you want. It is astonishing what "fanciers" or "the Fancy" have done in this direction. They have produced animals of the guaranteed pattern; bull-dogs, for example, with a lower jaw an inch or two in front of the upper; and with nostrils directed upwards rather than forwards. They have produced pigeons which tumble when they fly, and others which have long feathers on their feet. This has been done simply by breeding from the animals that were observed to have these peculiarities most distinctly marked. The same thing can be done with plants, and probably the finest wheats have been raised simply by selecting the best ears and sowing only from them.

The second way is really of the same nature, but it is actuated rather by watchfulness than careful and continuous selection. Most plants are induced to "sport," as it is called. That is to say, now and again a seedling will come up which is distinctly different in some feature from the parent. It is argued by the Dutch naturalist Professor Hugo De Vries, who has especially studied this trick of "sporting," that nearly all plants go through "a sporting period." This may occur only once in a thousand or many thousand years. A plant may go on, it seems, indefinitely without any change or progress, till its time comes, and then it "sports" in a host of ways. De Vries thinks improvement has come chiefly in this way rather than by "natural selection"; that nature makes such jumps rather than a slow and steady progress. He may or may not be right in his theory, but it is certain enough that some plants to-day sport in an extraordinary degree. Perhaps the plant that is to-day undergoing the greatest and most sudden natural changes is the evening primrose. It has innumerable offspring strangely different from the parent. But all florists notice such changes. Some very curious ones have occurred recently, for example, in the sweet pea and the tulip.

The third method is much nearer than the others to what has been called "creation." It is the method of crossing or hybridisation. It is very easy and simple to take the

pollen which hangs on the "anthers" of one plant, and put it on to the sticky head or stigma of another. If the plants are of different species, say a rose and a pea, nothing happens; the interference with Nature has no effect. But if the two are of the same family, say a peach and a nectarine, or a blackberry and a raspberry, the seeds may give rise to a new plant which is not quite like either parent, and which may, indeed, be very unlike the parents.

No better example could be found than the "creation" of the logan-berry and lowberry, the phenomenal and newberry, all of which have come from crossing the raspberry, and the blackberry. The logan grows a good deal more rampantly than the blackberry, and rather in the same way. It has a berry which is red and not black; but this berry is relatively as much larger than the raspberry as the plant is bigger than the blackberry. When they had once made or created this the gardeners could make others like it. By crossing the logan again with the blackberry they could turn the berry black instead of red, and increase, if anything, the vigour of the plant. Again, by crossing with some of the largest and sweetest varieties of raspberry, for example, the one known as superlative, they could enlarge and sweeten the new berry. Now, with these berries you could always make sure of getting the same plant again when you wanted to multiply it, by making cuttings or taking "layers." In other words, all the new plants are, in the first instance, actual pieces of the old plant.

When the logan was once "created" no further trouble had to be taken. But if new logan bushes had to be grown from the seed the work would be only just begun; for the plant would have to be "fixed" as well as created. With all trees and bushes plants can be multiplied in a variety of ways by taking pieces of the parent. Logans are "layered"; that is, the branch when first buried, takes root, and a new briar is formed. Fruit trees are budded or grafted; and it is interesting to record that budding is now generally preferred to grafting by the nurseryman.

A NEW FLOWER

A large and beautiful double flower gathered in the New Forest. It is probably a unique "sport," there being no record of its previous occurrence. It is known as Potentilla Reptans.

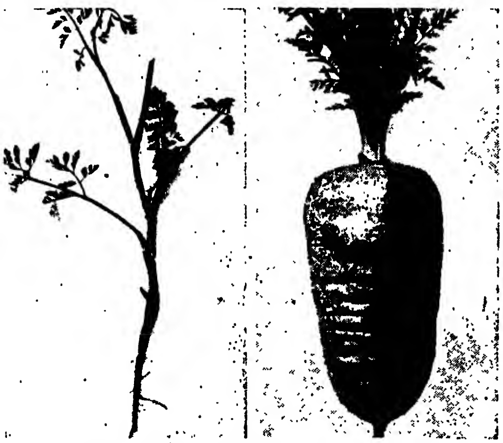
Roses and scores of plants are often multiplied by cuttings. But with most annuals it is often necessary, and always convenient, to grow from seed; and the creator must pay his attention also to "fixing." Some plants never, or very seldom, come true to the parent. There are, for example, some very fine dark flowered and almost blue-leaved tropaeolums which are entirely grown from cuttings. If the seed is sown, some of it is barren, and the rest untrue. But all "creation" must come by way of the seed. Everyone knows that Nature does not allow great jumps. She does not permit offspring to be raised from turnips and apples or any such monstrosities. Species remain distinct, even if they in the beginning of things grew from one origin.

Practically speaking, the gardeners and men of science who work at making new plants are solely concerned with crossing different varieties of the same species. But it is very astonishing what has been done within these limits. There are two difficulties. The first is to produce a seedling which is distinctly better than either parent. The second is to make sure of being able to multiply this seedling when you have got it.

Let us see how a man goes to work who wants to produce a new wheat. He is told by farmers that they want a wheat which is as big in the berry as A, as large in yield as B, as "strong"—that is, dry—and to look as transparent as C, and shorter and stronger in the stalk than any wheat. What does he do? In the first place, it is very difficult to cross, or marry, any two wheats. It requires neat fingers beyond the ordinary and a great knowledge of the nature of the plant to open the flower of A,

MAN'S CREATIONS FROM WILD NATURE

THE WILD CABBAGE AND ITS DESCENDANTS, THE CABBAGE, CAULIFLOWER, AND BRUSSELS SPROUTS



WILD AND CULTIVATED CARROTS

WILD AND CULTIVATED ASPARAGUS

WILD STRAWBERRIES AND THE CULTIVATED FRUIT OF THE MODERN KITCHEN GARDEN

at just the right moment, and to transfer the pollen from B. When he has done this, and at harvest time carefully garnered the seed of the plant, he has, of course, to wait a year until he can cross this A B plant with C. When at last, after years, he has crossed A with B, and A B with C, and A B C with a short-strawed variety D, he finds the progeny, the issue of this parentage, to be a weakling. It proves very liable to disease, perhaps, and has no very marked virtues.

Even if it turns out a good wheat that may, perhaps, be worth growing, he finds that the crop from the new creation is hopelessly mixed, some straws are long, some short, some berries big, some small. He has then to work for years selecting what he considers the true sort; and it may be ten years or more before he gets a variety which will "come true" without any eccentricities, or "robbers," as the French call the untrue plants.

How greatly the difficulty of creating and fixing is increased in the case of a fruit will be realised when it is remembered that trees may take up to twenty years to fruit. With a peach the experimenter who crosses A with B will have to wait seven or eight years before the progeny A B bears fruit, and the experimenter can see whether the offspring shows any improvement on the parent. He will have to wait another long period to see if the descendants come true.

The Great Discovery of Mendel as Illustrated in Plant Life

The work is easier than it used to be in the case of some plants owing to a strange law of heredity which was re-discovered in 1900. It is called the law of Mendel, who was an Austrian monk. This discovery was made in a monastery garden, and published in the same year that Darwin issued his "Origin of Species"; but very few people took much notice of the monk's pamphlet till it was re-read by some students in 1900. The wonderful workings of this law, about which there is still much dispute, will be explained elsewhere. The value of it is that it enables the Mendelian experimenter to tell which plants will come true and which will not. For example, in the case of sweet-peas it can be told with absolute certainty after two generations have been grown which plants carry true seed; and in the case of the untrue plants it can be told what sort of plants and in what proportion they will produce.

But, wonderful though the law may be, it has not removed the chief difficulties of "creating." It is still the case that the most successful of the makers of new things follow no law whatever. They have been so often and so deeply disappointed by crossing the plants which *ought* to give the desired virtues, that they work more or less haphazard, crossing more or less all sorts of varieties, irrespective of what may seem to them likelihood. A correspondence recently took place between one of the best English workers and the most famous of the American workers. After many years of experimenting they wrote to one another to say that they had achieved the best results by a sort of accident.

How the Oat Became Strengthened and Improved by Accident

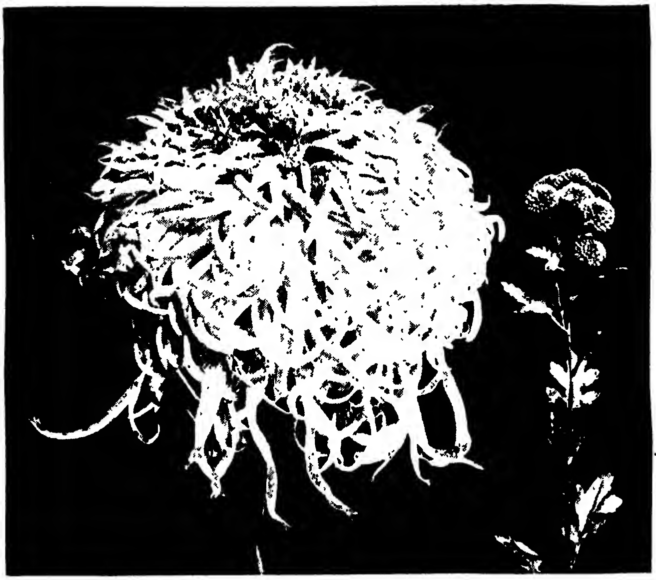
Some of the examples are interesting. After all sorts of cultivated oats had been crossed with very little results, a trial was made, almost by way of a jest, with the wild oat. Now, the wild oat is a rather useless grass. It bears a very fair amount of grain, but each grain is so small as to be quite useless. But when the wild oat was married to a particular variety of cultivated oat, which had itself a long and complicated ancestry, it was found that the progeny had the health and vigour and high yield of the wild plant with the big grain of the cultivated variety. The parents had, indeed, passed on only their chief virtues, and apparently none of their deficiencies. In this way an oat was produced which added a good many shillings to the value of the oat crop per acre all over the world. In the past most of the great successes have been made in this way, or by the sudden appearance, no one quite knows how or why, of some plant which "sported," and has been carefully preserved by those on the look-out for the accidental wonder.

Rough and Ready Chemical Analysis by Wild Animals

Sometimes the new creation has been recognised when produced only by an accident. This happened in the case of one of the best mangolds now grown. Out of several very mixed rows of mangolds from a particular cross, one particular root was attacked by rabbits. A wire was put round, and even then the rabbits continued to attack this in preference to the others. Seed was, therefore, grown from it, and in the second generation it was noted that again the rabbits showed a decided preference for this sort. An analysis was made of the root, and it was found that it possessed a considerably higher proportion of sugar than any known mangold at that date.

The fact that this was discovered only by accident, indicates another of the difficulties under which the maker of new plants labours. But when all is said, and when all the failures and set-backs, which are many, are duly reckoned, it remains true that the success is such as to give great hope that progress in creating healthier and richer and, so to speak, more highly condensed crops will be rapid, and the wealth of the human race increased. The only real addition to wealth which is likely to conduce to the health and happiness of men is increased produce from the land.

The measure of future success is the degree of present achievement. Much has been done, even in the few years of this twentieth century. To begin with wheat, which has been called the staff of life, the success has been sufficient to give a fair expectation that wheats will be made which have all the cardinal virtues desired in particular localities. M. Vilmorin, who is the largest "maker" of new plants in the world, has recently produced wheats which do quite as well when sown in the spring as in the autumn. Here, then, is one new and most valuable virtue implanted in wheat. These new wheats of his also yield very heavily.



CHRYSANTHEMUM FLOWERS—A CONTRAST IN CULTIVATION "LADY TALBOT" AND "BABY GEM"

At first his customers—who sowed his wheat on very rich soil—complained that the straw was too long and the crops were the victims of strong winds and heavy rains. Within a few years he produced a wheat which yielded quite as heavily as the others, some say more heavily, and was short and stout in the straw. These French wheats are generally believed to be deficient in what is known as "strength"—the grains, that is to say, are without the hard, semi-transparent look of wheat of the best quality.

The question of quality was taken up scientifically by the scientific workers of Cambridge University, who worked, unlike M. Vilmorin, strictly according to the rules of the Mendelian law. Within a few years they have "created," they believe, what they willed. It is as yet too early to speak confidently of the exact virtues of these "Cambridge wheats," of which very much has been expected. But, beyond all question, the new Cambridge wheats have this virtue, "strength," which had been previously especially marked in a variety known as "Red Fife," and have succeeded in keeping the "strength" of this variety with the higher yield of other less strong varieties.

One of the principal drawbacks to high-yielding wheats is their liability to "rust" and other diseases. The Cambridge men of science believe that they have also produced a "rust-proof wheat," and recent experiments confirm their faith. Some similar advance has been made in Sweden. No doubt as yet farmers are a little sceptical about the excellences of these and other new "creations," and it may be that they are inferior in essential points to some of the older wheats, but their creation has proved the extraordinary degree of control now exercised by men of science over plants. These workers have undoubtedly implanted the particular qualities they sought.

A more clearly demonstrable success in scientific breeding has been achieved in the making of sugar-beet. Messrs. King, of Coggeshall, succeeded in making a root which was free from the multitude of rootlets belonging to other beet plants. It was found that these rootlets seriously reduced the value of the crop, since when torn, as they must be torn, in pulling and cleaning the roots, they let out valuable juices. In making this, so to speak, rootless root,

they sacrificed some of the sugar. The new beet was bigger and cleaner, but in some respects not so condensed as the older root. But there is no reason in the nature of things why the old virtue and the new should not exist together in a new plant presently to be produced.

A very astounding advance in this class of crop was made years ago in Sweden, when "Swedes" were made; and some new experiments, of which nothing as yet has been heard, have recently reached completion, and a new plant of high value to the world will appear.

Many quaint and useful advances, suggesting all sorts of possibilities have to be recorded in vegetable-making. Messrs. Sutton produced a cabbage which bears the stout "head and heart" of the ordinary cabbage, as well as a stalk covered with leafbuds which we call Brussels sprouts. This curious and useful plant has emerged from a single wild plant that may still be found on the cliffs of England. The kohlrabi, which most people regard as a sort of turnip, is in reality a cabbage with a turnip-like stem. This has emerged from the cabbage, and by careful crossing varieties have been made which are as well suited for human food as the older kohlrabi for cattle or sheep food.

THE DEVELOPMENT IN PEAS
The "World's Record" peas contrasted with a type of a few years ago.

In such vegetables, or so-called vegetables, as onions, potatoes, tomatoes, and marrows, the increase in size and quality during the last generation is beyond all doubt. With every generation the plants bear better and fuller crops, and man benefits.

Progress is quite as apparent in fruits. Scores of new apples have been made, excelling older sorts in flavour and size, and differing immensely in time of bearing. Messrs. Rivers, who have been working for many years at these problems, have combined the nectarine and peach, to mention one only of many feats of "creation." A great deal has been written on Mr. Luther Burbank's work in America. He has become known as "the Wizard of the North," and is generally supposed to have produced pipless apples, stoneless cherries and other queer fruits. He has not done all that was reported in newspapers, but fruits so unnatural and at the same time useful as to be almost without pips have been "created"; and beyond all question the pulp, or edible fruit, has been enlarged out of all original relation to the germ, whether it be stone or pip. There is no reason why we should not one day have apples with merely a relic of the core or pips, and plums with small, shrivelled stones which can scarcely be detected.

We have seen within a generation new oats that have added in favourable places a "combe" or half a quarter to the acre. No one doubts that the "Abundance" oat, which was produced at Warrington by Mr. John Garton, one of the most skilled of the hybridisers, began an advance which means millions to the producer; and so in wheat it is likely—it is, indeed, now happening—that each locality will have a variety of wheat possessing such qualities as will enable the ground, whether it is poor or rich, to yield very much larger crops.

The logan-berry and its derivatives are very striking examples of what may be done in the production of quite new fruits. Already you may see acres of land, which were once under hops, covered with this new fruit. It is very extraordinary how enormously strong and lusty many of the new creations are. No briar comparable with the logan and lowberry in vigour of growth has been seen. Though one of the plants is the raspberry, which of course is not a very free grower, the logan sends out bigger and stronger shoots even than the blackberry. The fruit, again, is very much bigger than either blackberry or raspberry, indeed, if the plant is properly cultivated it is twice as big. It is this fruit as much as anything that gives hopes of incalculable advance in the future. If a cross-bred—that is, a new plant—can excel its

parents in all the cardinal points, it will not be necessary to climb slowly and laboriously to perfection, in the old and Darwinian manner, by selecting and selecting the best year after year.

The same phenomenon of unexampled and unexpected vigour in the progeny is remarkably illustrated in some of the newer flowers. As good an example as any, which will be known to all gardeners, is the Dorothy Perkins climbing rose. Its vigour of growth is irrepressible, whether it is given support or allowed to ramp over the ground. If left alone it will "layer" itself, and produce new plants with even more certainty than the wild bramble. It will flower on occasions from midsummer to midwinter. Now, all our roses, which are too many to remember, grew from as few as four, perhaps three, original stocks. By scientific crossing they have been made to flower many months longer than any of the original roses, even the China rose. In the Penzance briar the sweet leaf of the wild sweet-briar has been wedded to the brilliant reds and yellows of the more elaborate bedding-roses.

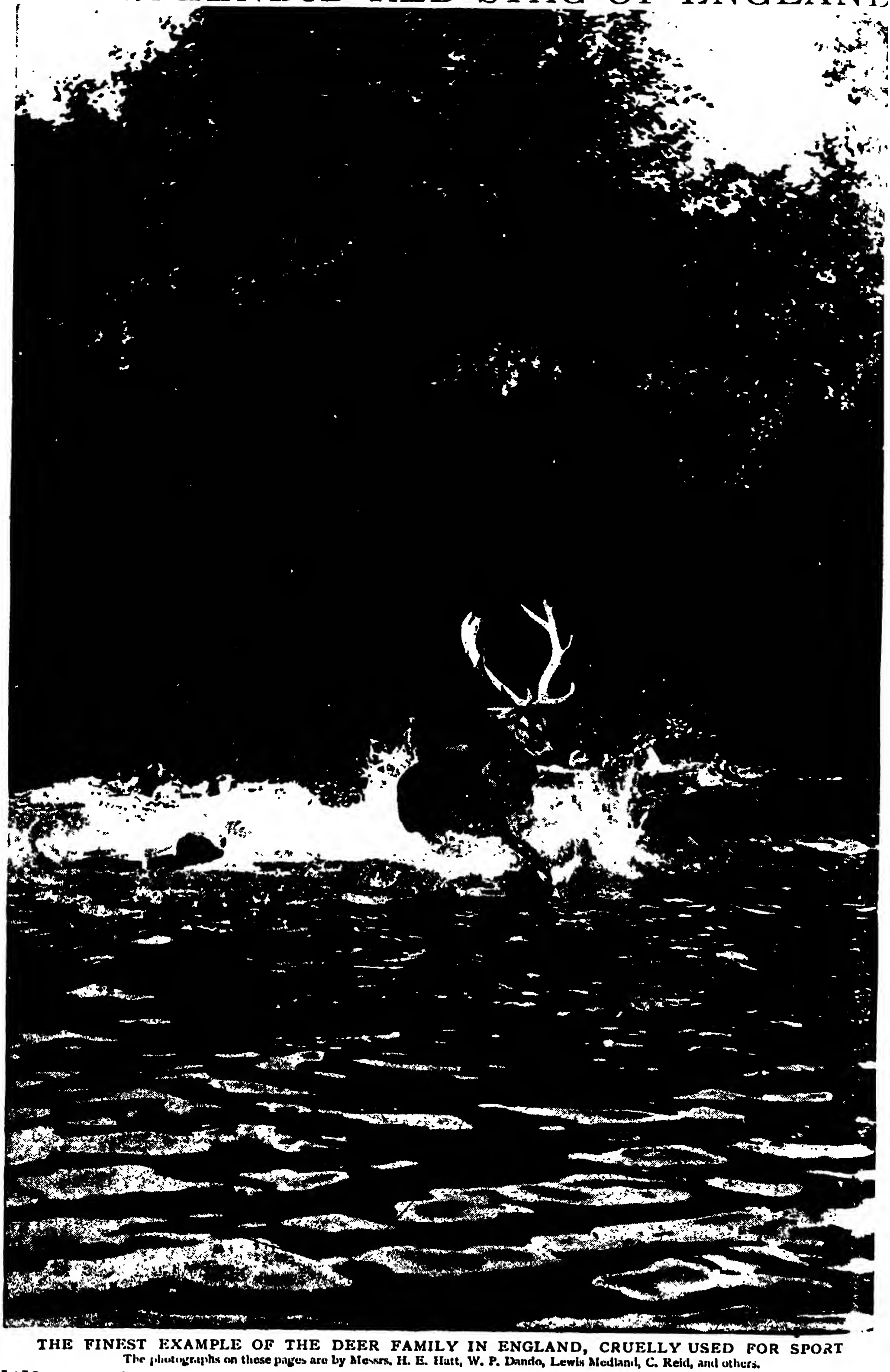
A HYBRID ORCHID—CYPRIPEDIUM

It is a surprising thing that, so far, more effort has been spent on improving flowers than fruit and vegetables and grain. One firm, for example, spent fifteen years in producing a gloxinia with a maximum of white in the bell; and the efforts spent on enlarging the size and deepening the colours of such florists' flowers as begonias or calceolarias cannot be estimated. The point is that these efforts have been marvellously successful—the size of the flowers has been trebled; the range and intensity of colour have been magnified beyond description. Much of this has been achieved by selection. Yet more astonishing results have followed the experiments on orchids; and in this instance the development is due not to selection, but to crossing or hybridisation.

What has been done with flowers is the measure of the possibilities of development in all plants of whatever sort they be—wheat and grasses, bulbous and tuberous food-plants, fruit and vegetables. The new qualities grafted on to plants are not always apparent on the surface, but they are not the less valuable for being more or less invisible. The Cambridge men of science believe themselves to have "created" a wheat which is "rustproof"; and inasmuch as the greatest enemy to new creations is greater liability to disease, the manufacture of this virtue is of cardinal importance.

The chief marvel of some of the newly created fruits is the date of flowering and fruition. When you have produced an apple which flowers after the period of the late frosts, which seldom do damage after May 14—you make apple-growing a very sure and certain industry instead of a gamble. Some of the Paris growers have succeeded wonderfully in extending the fruiting period of strawberries. Several varieties may be procured of what are called perpetual strawberries. In a moderately congenial climate they will bear fruit into late autumn. A dish of outdoor strawberries has been picked on Christmas Day. These perpetual strawberries indicate well the handicap which man has to face in attempting to defeat the seasons and extend Nature. The later the sort, the less free the fruiting. You can create a plant to fruit two months later than the normal, but you cannot make it fruit properly. It is as if the plant felt a reluctance to travel beyond its range. This, of course, is not always so. The Dorothy Perkins rose is proof enough that new habits may be correlated with new vigour, but some compensating weakness is more common than added vigour.

When one reviews the whole range of experiment, and sees what has been done and what not done, one is left with a sense of high expectation. The value of the plants men cultivate may be enhanced in as great a degree as the productivity of the ground. Plants may develop a nature which may in some measure defy the seasons. Wherever we look forward, the hope of true wealth and a kindlier land colours our mental prospect. Science does not probe in vain the lesser secrets of Nature.



THE FINEST EXAMPLE OF THE DEER FAMILY IN ENGLAND, CRUELLY USED FOR SPORT

The photographs on these pages are by Messrs. H. E. Hatt, W. P. Dando, Lewis Medland, C. Reid, and others.

THE SACRED DEER FAMILY

The One Semi-Wild Creature that Extends its Range at the Expense of Man

THE MYSTERY OF THE ANTLERED HERD

A MINOR disability of the man in the street is the circumstance that he does not own a deer forest. As a fact, there is a majority of Britons who not only do not possess forests but have never seen so much as a deer, unless to behold the stark carcase of the animal in a game-dealer's shop be called seeing one. By the greater number of London's millions the speeding deer has to be taken on trust, as it were, as has the okapi, which the Congo forest hides, or the musk ox, whose desolate environment lies beyond the range of most of us.

There are deer to be seen in England, it is true. Although the animals, removed from Hyde Park for the public fair which marked the Coronation of Queen Victoria, have never been replaced, there are herds of varying sizes in the Royal parks at Windsor, Richmond, Greenwich, and Bushey; and a few years ago an unofficial census showed that England possessed no fewer than 400 parks or paddocks sheltering deer. Epping Forest has deer, to be discovered by the silent watcher, and in the New Forest some roam at will, having made their home there after escaping from private keeping. In this connection it is a little perplexing to learn, on the authority of a Minister of the Crown, that while deer are permitted to be at large in Epping Forest, every effort is made to kill them down in the Hampshire wilds, which are nearly twenty times the size of the North London demesne.

Scotland is, of course, the principal home of deer in Great Britain. The stock of deer north of the Tweed was stated the other year to be well over 200,000 head. The estimate is probably conservative, for deer forests have latterly been vastly extended. Thirty years ago, the total area of these sporting estates in six Highland counties covered 1¾ million acres; four years ago they had extended to within forty thousand of three million acres, or between one-sixth and one-seventh of the entire country! When we hear in Parliament of arable land being thrown into deer forests, and the farmhouses blown up with dynamite to clear the way for the sportsman, we cannot view the extended range of the deer with equanimity.

We are not concerned here, however, with the moral and economic aspect of the matter, but as naturalists, and as such we cannot but rejoice at the success of those who have stocked barren acres with the beautiful deer, for these animals are the only survivors of our native fauna, other than truly domesticated animals, which have increased in numbers with the advance of civilisation. Indeed, it is an inspiring thought that some of our Highland forests are becoming true sanctuaries for wild life, to which the golden eagle has returned in safety, where the old black rat still maintains a place, where the wild cat still has a footing, and where the pine marten climbs the forest-trees with sinuous grace. If only the "ardent sportsman" is kept in check, all may yet be well. The curse of wild Scotland is not the legendary nine of diamonds, but the expert enthusiast who cries out to his keepers and to the owners of forests adjoining his own: "Trap, trap *severely*; offer rewards for foxes and eagles and hawks and owls, and all such *vermin*." Such is the advice given in a standard work on the subject, written by a man to whom every living thing in a deer forest, beyond deer and grouse, is nothing but vermin.

Well, to rent a shooting in Scotland is, like the owning of a deer forest, another of the things from which the average British workman determinedly abstains. Five thousand pounds a year for a sight of and a shot at a flying stag is one of the items fixedly excluded from the working class budget, so the deer forests of Scotland do not

greatly extend the knowledge of their antlered monarchs among our industrial population, and we come back to the original proposition that deer must, to a great extent, be taken on trust. Which is a pity. For there are few animals surviving that give the student so furiously to think.

The Amazing Annual Growth of the Antlers of the Deer Family

The man of the street always pictures the stag with towering antlers; he does not realise—how should he?—that these massive weapons are developed every year, then cast as naturally and easily as a bird discards its plumage. This growth and discarding of antlers is quite one of the strangest phenomena of Nature. It cannot be compared to the method of moulting pursued by the larvæ of insects, for that process leads up to a definite metamorphosis beyond which there is no change. This is an annual process. Perhaps it may be more justly compared with the moult of the crab or the lobster, which crawls out of one shell, and at once develops another; or with the successful effort of lowly organisation to replace lost limbs or important organs.

It is this casting of the antlers which differentiates the deer from all other animals, with one notable exception. This is the prongbuck antelope, which is a connecting link between the two families. The prongbuck develops a pair of small, permanent pointed horns from the top of the skull, but, from these, sheaths of branching horn arise, to be cast every autumn, as in the case of the antlers of the deer. This, and other peculiarities, constitute a puzzle, so that naturalists do not quite know where to place the animal, whether in a family to itself or as a sub-family of the Bovidæ. As we shall not meet this anomalous animal again, it may be noted that its home is the temperate regions of the western portion of America.

An Asiatic Deer that is Kept Alive Only as a British Curiosity

Antlers are, as a rule, carried only by the male deer. There are exceptions, however. Some females, which are neither unsexed nor infertile, produce antlers when young, and grow them from year to year. And some aged female deer, after rearing several fawns, grow small antlers, as some aged female birds develop plumage approximating to that of the male bird. We cannot say, again, that all stags cast their antlers once a year, for some deer have no antlers; while there is one species of deer, the milu, or Père David's deer, the young stag of which casts its antlers twice a year!

A romantic interest attaches to the animals of this species. The milu has never been definitely traced to its native home, it was known only in the Imperial Hunting Park at Peking. During the Boxer rebellion, the walls of the hunting park were broken down, and the deer fled, and were captured and eaten by the natives. And it is believed that the only living representatives of this interesting species are those to be found on the Duke of Bedford's estate at Woburn. Happily they breed there, so there is the possibility of their owner having it in his power to furnish Asia with the nucleus of what may in time become a powerful herd. It is a fascinating prospect, of which the Duke of Bedford is far too enthusiastic a friend to Nature not to realise the romantic significance.

One other qualification, and then we end the exceptions which go to prove the rule that the males alone of deer carry antlers. The reindeer of both sexes carry these weapons. As these animals have already been dealt with in the last chapter but one, we may dismiss them, to return for a moment to the consideration of the antlers of the normal deer.

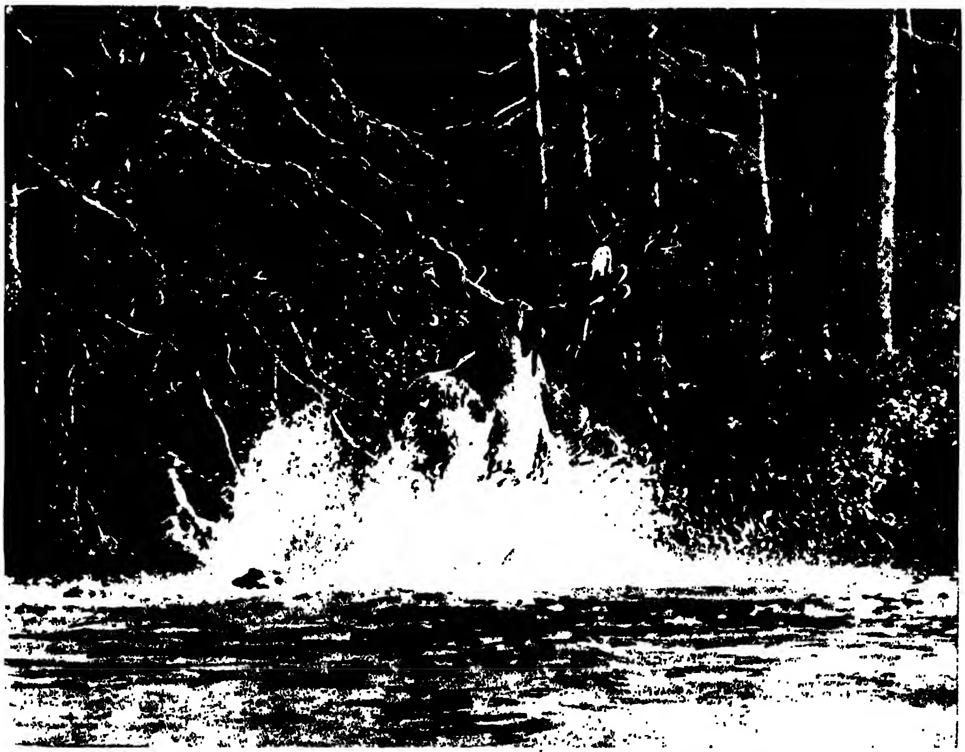
The Story of the Growth and Loss of the Deer's Weapons of Defence

Sir Harry Johnston surmises that the horns of all deer may have originated in the form still preserved by those of the okapi. How the antler has developed from a primitive bony prong we have already read on page 302, where the history of the deer horn is given. It remains, therefore, to be noted in what manner the antler of contemporary deer arises.

The antlers originate in a pair of bony protuberances on the upper part of the forehead. Upon these develop velvety knobs, which are liberally supplied with blood-vessels. The knobs develop rapidly in size, until the maximum dimensions are attained, small in the young animal, increasing in size with each year of the deer's growth. The blood courses feverishly through the investing velvety skin, and bony matter is rapidly deposited, so that in the course of some ten weeks the mighty antlers, which may weigh over seventy pounds—which in the extinct Irish elk are known to have weighed as much as 100 pounds—are completely formed. At this stage the bony rings at the base, through which the arteries pass, begin to thicken and close up, so compressing the blood-vessels and terminating the connection between the antlers and the rest of the body.

THE GIANT ELK OF NORTH AMERICA

A YOUNG ELK, OR MOOSE, SWIMMING ACROSS A LAKE



AN ELK, OR MOOSE, LEAVING A STREAM FOR THE FOREST

The "velvet" in which the antlers are invested is rubbed off against trees or other convenient obstacle, and the stag is ready for battle—a living animal armed with a huge mass of dead bone. Such the antlers in their perfect state really are. They serve for the duration of the breeding season; then the living bone at the base of the antlers is absorbed, and the antler is shed. The bony pedicles almost immediately reappear, the velvety knobs sprout afresh, and the entire growth is renewed. The whole process is unique and marvellous. Here is an animal growing and discarding a great quantity of solid bone every year, yet the mighty rhinoceros perishes when his teeth wear out, for the reason that he cannot continue their growth. If only the elephant could shed and renew its tusks in the same way it would be in no danger of extermination: we should "farm" elephants for their ivory as we "farm" ostriches for their feathers.

A MODERN MONARCH OF THE GLEN—THE RED DEER

The deer family is an ancient one of eleven genera and some threescore species. Acquaintance with one family, the chevrotains, may be renewed on page 302. Deer are to be found all over the world, save in Australia and that part of Africa south of the Sahara known as the Ethiopian region. Their absence from the latter territory can only be explained by the fact that their place is there taken by the antelopes.

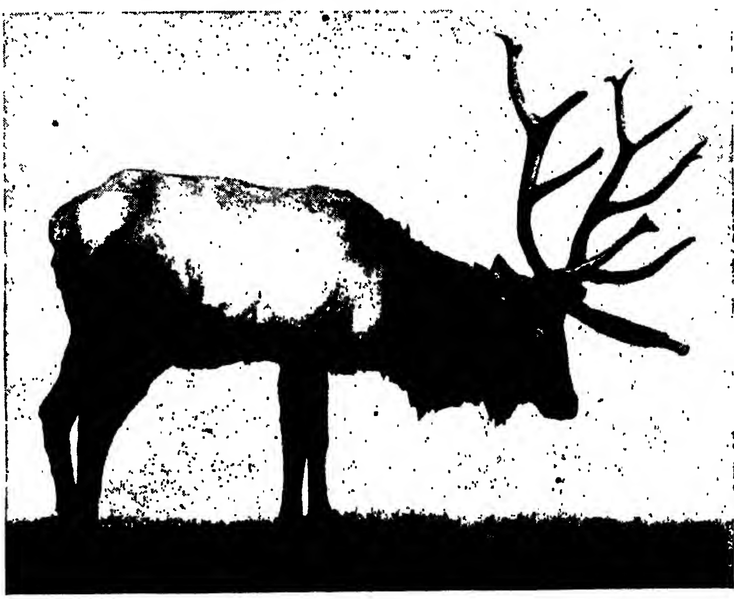
The splendid red deer was not the first of the family to reach Great Britain, but arrived in the wake of man, late in the Pleistocene period. It still has a far extended range, in spite of the denudation of former forest land. Several species are to be found distributed over Europe, Northern Africa, North America, and Asia north of the Himalayas. Reddish brown of coat in summer, with the head and legs tending to grey, and with a yellowish patch on the buttocks, the red deer in winter assumes a coat of longer hair, which becomes a brownish grey. Standing fully four feet in height at the shoulder, the adult stag may weigh between twenty and thirty stone, but records of still heavier beasts are kept. These fine animals are still to be found wild in the Highlands, but the bulk of them may be described as semi-domesticated. At any rate, in many places they gather during the winter like sheep to be fed by the servants of the estate. Like most of the deer family, they are harmless, except during the short breeding time. At that season, when the stags begin to roar, they are formidable and fierce enough to try the nerves of the boldest man. For all their acquaintance with the sight of human beings, these animals still retain their instinctive terror of man's scent. With the wind blowing towards him, the present writer has walked to within a hundred yards of where a dozen fine stags crowned a solitary Highland hilltop. The deer stared with a sheep-like curiosity and stood their ground, though uneasy. Given a turn of the wind to carry the scent of a man, they would bound away in the wildest panic—except, of course, in the breeding season, when, in such case, a man's life would not be worth five minutes' purchase.

Here is a curious little illustration of the unseen war waged between deer and domesticated animals. A certain Scotsman hired a wild hillside, and on it pastured

over a thousand sheep. Deer belonging to the same property entered, as they were at liberty to enter, upon the sheep-run. Being the stronger animals they quietly and slowly got the better of the sheep, not by combat, but simply by reason of the fact that, as the bigger and more active creatures, they got the best of the food, and ate that which the sheep needed. The farmer complained to his landlord that the deer were too numerous, or that the hill for which he paid was too open to the depredations of the deer. Well, the deer could not be disturbed, so the sheep must go. The landlord offered to take over the sheep at a valuation, and did so, and Scotland was fourteen hundred sheep the poorer. The result is that a grand heathery and bracken-clad hillside is rapidly losing its grouse. Sheep make regular tracks along which the young birds can run to and from their nests; deer do not. With these tracks obliterated the young birds get lost and drowned, or killed by cold. Which is a word in place for the sheep upon a Scottish hillside.

Asia is the home of several allies of our red deer, and one of these, the hangul, or Kashmir stag, stands nearly half a foot higher at the shoulder than the British species. These fine animals are being exterminated through the ruthless manner in which they are slaughtered when, gathering together into herds, they descend into the valleys, driven thither by the snowfall on the mountains. The nearest ally of the hangul is the wapiti, which is linked by the former animal with our red deer. The wapiti, of which the best known example is famous throughout the northern half of the American continent, though now in sadly dwindling numbers, is the second largest of the deer tribe, standing, in the biggest examples, four and a half feet in height at the shoulder, weighing 700 pounds up to 1000 pounds, and carrying prodigious antlers. It might be thought that this bony burden would impede the flight of the animal through the forest, but the wapiti so disposes his head in running that the horns are laid flat along the back, and the antlers may even serve as a protection against overhanging branches rather than as a hindrance. Except during the mating season, the adult stags keep apart from the females. When the autumn comes, however, the battles between the males are indescribably savage, and at such a period a male wapiti is said by good judges to be, viewed from the point of a possible antagonist of man, a veritable fiend. The wapiti, like most deer, is a bold swimmer at need, and capable of considerable speed when on the run.

Passing the pretty sika deer, of which the Japanese species is typical, we come next to the fallow deer, which is represented in Great Britain by two types, the spotted and the unspotted, the latter a deer of dark uniform brown. This species is allied to the sika group. How we got the fallow deer is a debated question. Certain isolated remains of Pleistocene origin have been regarded as those of this animal, but the evidence as a whole goes to show that the fallow deer came much later. Whether it was an artificial importation, and by whom, naturalists are not yet agreed. The animal is less able to take care of itself in our hard winters than the red deer, and during severe weather receives hay and corn. Most deer leap at trees, and with their antlers beat the



A NATIVE OF ASIA AND NORTH AMERICA—THE WAPITI

fruits from the branches. The special delicacy of the fallow deer is the horse-chestnut.

The chital and sambar group—the former a gay and handsome deer of India and Ceylon, and the latter "the woodland deer of South-Eastern Asia generally"—suggest that, in course of time, we might get a deer which, if permitted to live its natural life, would develop permanent antlers, and not shed them. Red deer hinds at times produce antlers, as we have seen, and the female reindeer which first carried these weapons must have been a "sport" that found antlers useful for the protection of her fawn, and passed on the peculiarity. And it is not impossible that from the chital or its ally, the sambar, there might arise the curiosity indicated. For there is great irregularity in the shedding of the chital's antlers, while the sambar buck is known at times to carry his for at least two seasons.

Allied to these interesting animals are the hog deer, so called from their pig-like habit of rushing, when alarmed, with head down through the long grass in which they make their home. This style of carriage applies also to the muntjac, an animal ranging throughout the hill forests of India, Ceylon, Burma, Siam, China, and Malaya. In addition to antlers, the muntjac stag is armed with projecting canine teeth in the form of tusks, and, when attacked, uses these with considerable force, so as to produce an ugly gash in the flesh of an antagonist. One species of muntjac, the hairy-fronted, whose short antlers are almost concealed by the bushy hair upon the forehead and top of the head, leads us on to the true tufted deer, natives of China, in which this development of hair is still more curiously pronounced and the antlers increasingly attenuated, while the tusks are devloped in correlation with the diminution of horns.

This peculiarity as to dentition reaches its culmination in the musk deer, which, like the Chinese water deer, is destitute of horns, but has the upper canine teeth continued into tusks three inches in length.

To what extent these implements serve for strife is not certain, but native testimony is to the effect that the musk deer uses the implements in digging up certain bulbs. To catalogue the nature and purposes of the many external glands which distinguish the various species of deer would task the most expert student of the subject, but the glandular abdominal pouch from which this deer gets its name must not be passed without notice. The gland in the adult male contains about an ounce of a secretion of a powerful musky odour. When first obtained it is overwhelmingly strong to the human nose, but it rapidly dries, and lo, it is the musk of commerce which scents charms and amulets beyond number. The scent is extraordinarily persistent, the smallest

JAPANESE DEER, WHICH ARE COMMONLY ACCLIMATISED IN ENGLISH PARKS

NIMBLE DEER & QUAINT CHEVROTAINS


JAVAN CHEVROTAIN


INDIAN CHEVROTAIN

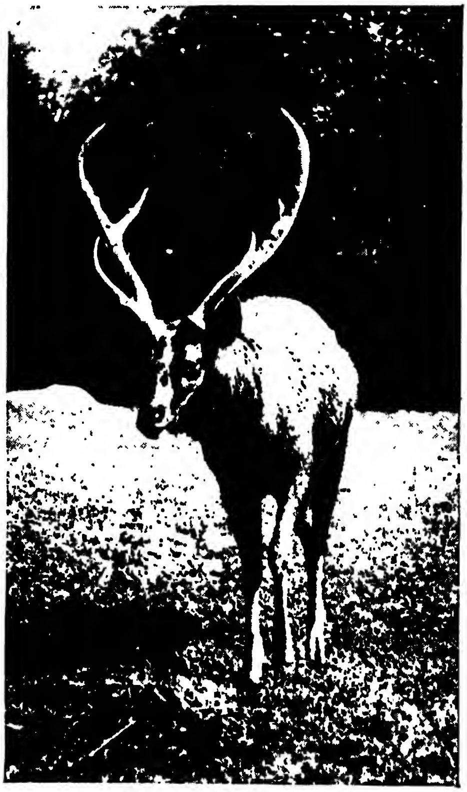

THE FALLOW DEER OF GREAT BRITAIN


INDIAN MUNTJACS


THE MUSK DEER

fragment retaining its powerful odour unimpaired for years.

The musk deer are among the smallest of the family, and we pass now to the monarch, the elk, or moose, which, though confined to Northern Europe and to North America, once roamed in large numbers over parts of England. Some of the finest specimens are to be found in Alaska and British Columbia —where elk bearing antlers with a span of seven feet have been shot in recent years. "A very steep animal," was a schoolgirl's description of the elk, and she certainly had a right conception as to the creature's dimensions, for "steep" it is, between six and seven feet high at the withers. For the purpose of comparison, it is interesting to remember that an elk standing 6½ feet at the shoulder is as tall as would be a horse of 19 hands! But the elk does not show himself quite to the best advantage, for he carries his short neck in a horizontal position, and lower, therefore, than the exalted withers; and this fact, coupled with the strange shape of the head, gives the animal a somewhat grotesque appearance. The female, lacking antlers, looks still more uncouth, the large, donkey-like ears being quite unlike the trim and picturesque pattern which we expect of a member of the deer family.


A FINE SAMBAR DEER

But those long ears are not without purpose. When the elk disposes itself to rest or chew the cud, the ears are constantly in motion, one backward, the other forward, and their sense of hearing is extremely acute. Added to hearing is a very keen scent, to which full play is given by an ingenious trick. When he is coming to rest, the elk takes a short turn and sleeps below the wind of his fresh track, so that if an enemy follow up the trail he must be heard or smelt before getting within shooting range. This seems a parallel development of instinct to that of the wounded African buffalo, which turns aside to lie down and await its assailant in the same way.

Canada is rightly jealous of the safety of her grand big game. The shooting of elk is limited under licence, and many of the old arts practised for the destruction of this splendid animal are discountenanced. In summer-time the elk betakes himself to deep swamps, where he nuzzles far down in the water, immersing his head to the ears, to pull up aquatic plants, making a prodigious blowing to free his mouth and nose of mud and water. This act betrays his otherwise unsuspected presence to the hunter, and it was of old time the practice to row at night with a light in the boat to the spot, and shoot the elk as he gazed in stupid wonder at the flare. This is not done now, nor is it permissible to hunt the elk with dogs.

Another popular sport was to hunt the elk on snowshoes. This may still be done when the snow affords fair running, but not when a thaw has been followed by a frost, so that, while the surface will safely carry the snowshoed hunter, it lets the hoofs of the elk sink at every stride. Stories of the hunting of the elk embodying these devices are now out of date. The elk must be tracked on foot; and as he runs with amazing swiftness through log-strewn forests, taking five-foot trunks in his stride, it requires a staunch hunter to come up with him if he once gets a fair start. And, even should he pause in the forest, he is most difficult to locate, so well do his long limbs harmonise with the saplings around him and his general body outline merge in the colour-scheme of the forest. Long may he elude the only foe that he has to fear—the man with the gun in his hands!

The roebuck brings us back to Britain again, where this handsome little animal is indigenous. Its height when fully adult is only 26 inches at the shoulder, but the head is boldly carried, so that its inches

seem greater. At certain times the roebuck is an exceedingly fierce little animal, and has been known to gore a man to death. It strikes sharply with its forefeet, but in this respect is naturally not so deadly as the larger deer. A red deer can rip a hound open with its sharp hoofs, while the elk, if approached too closely, will swiftly turn and trample a pursuer to death. The reindeer, too, has undoubtedly ability in the same direction. Seeing that roe deer have been natives of Scotland from Pleistocene times, they may feel well justified in defending themselves against intrusion, and, size for size, no animal does it better, even the doe using her feet with effect and butting with her head in defence of her fawn with as good will as an elephant shifting a bogged gun-carriage.


THE AXIS DEER OF INDIA AND CEYLON

But the strangest feature in the natural history of the roe is the fact that the female has the power to suspend the pre-natal development of her young. Perhaps it would be more correct to say that she has not now that power, but that the arrest of growth has become habitual. The mating season is in July or August, but the embryo remains absolutely undeveloped during the next four or five months. The actual development takes place between December and May, the period of gestation being only five months. We have a corresponding instance in the badger, in which, at the will of the dam, the young may be born at the end of the normal period—less than five months—or at any time within fifteen months. These two strange phenomena have no parallel, so far as is yet known, in the story of the whole mammalian order.


VENEZUELAN BROCKET

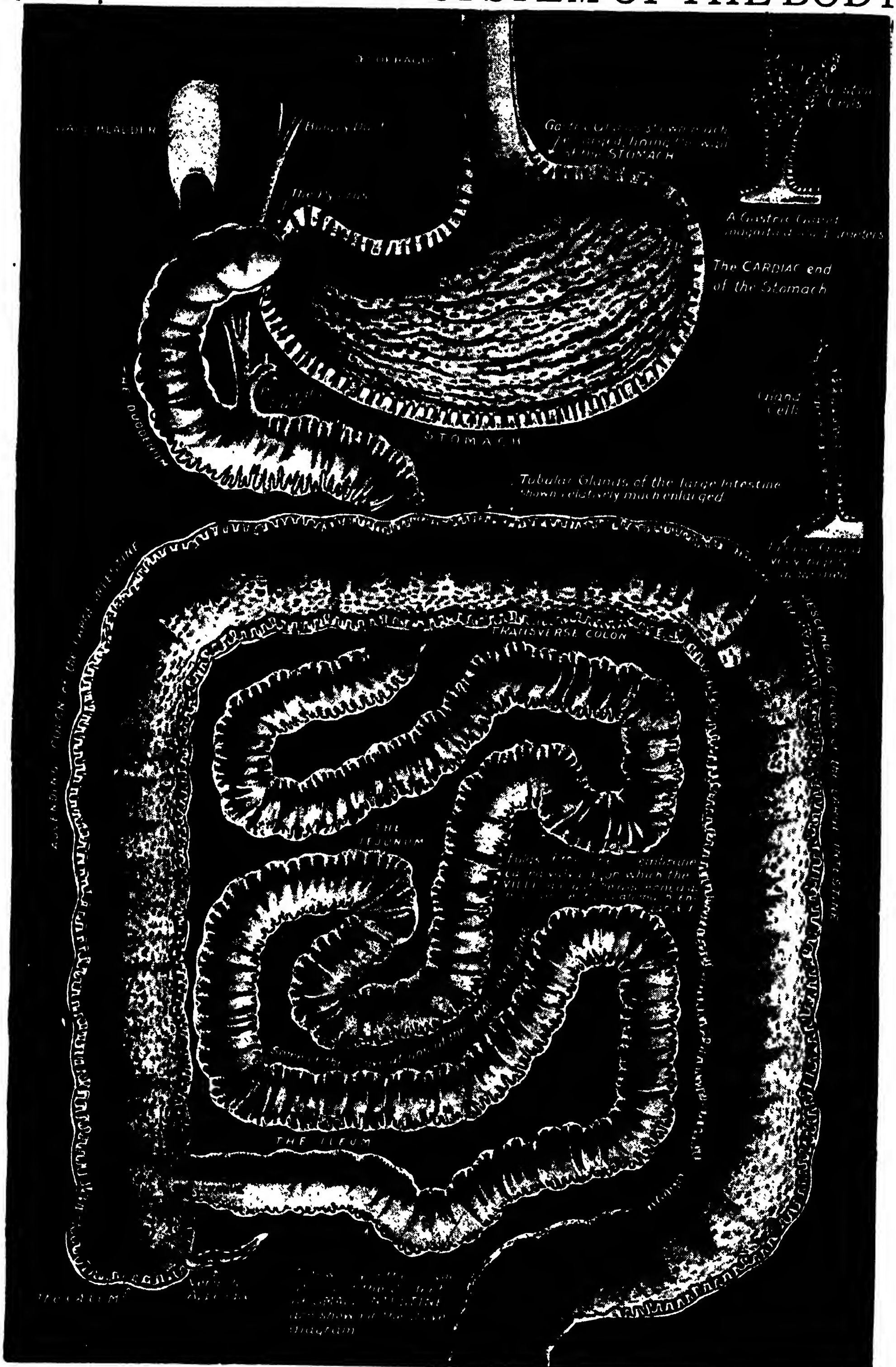
There remain still the smaller American deer, which comprise some notable varieties, differing considerably in certain points from those of the Old World. One of these is the little pudu, a deer scarcely larger than a hare, and possessing only tiny, spike-like antlers. A second group is the Mazama, or brockets, the latter name being applied on account of the resemblance they bear, in point of horns, to young red deer stags, which are so called when bearing their first antlers.

The pampas and marsh deer are represented by several species; the white-tailed or Virginian deer; the mule deer, so styled from the prodigious size of its ears; the black-tailed deer of Columbia, which has representatives in Alaska and California. These are animals with which students of the fauna of the American continent are familiar, but they possess no special claim to detailed notice in this place.

It is with the æsthetic, rather than the economic, interest of deer that we are here concerned, but it may be noted that these animals have always been an important source of food supply to man in the wilds. Like other large herbiforous animals, deer do great damage to crops—a fact painfully familiar to the Scottish farmer whose land adjoins an insecurely fenced deer forest. In return for the toll thus levied, however, we in the United Kingdom claim the venison of the deer, for which the flesh of the roebuck is best. The hide affords leather; the horns go to the cutler; and the chips of these implements yield ammonia, popularly known as "hartshorn oil."

New Zealand, which had no mammal bigger than a bat, now possesses large herds of magnificent red deer, from a few animals sent over by the Prince Consort from Windsor, and others contributed by Lord Dalhousie. So well have the animals profited in their new environment that their dimensions and antlers exceed anything seen, as a rule, in the land of their ancestors

THE ALIMENTARY SYSTEM OF THE BODY



A PICTURE DIAGRAM SHOWING THE ENTIRE COURSE OF THE FOOD THROUGH THE BODY AND THE PROCESSES BY WHICH IT IS ABSORBED INTO ITS SYSTEM

THE ALIMENTARY SYSTEM

Food in its Course Through the Body and the Chemical Action on it before its Absorption

ORGANS WITH MANY AND WITH NO USES

From the Latin verb *alo*, I nourish, we derive, in English, the word aliment, or nourishment, and also the term alimentary system, to indicate that series of structures in our bodies which exist for the intake and adaptation of food or nourishment. These, again, are not peculiar to man. Every living thing must have some kind of alimentary system, or it would die of starvation. The amœba may not have developed any special organs visible to our eyes for the purpose, but it must have its machinery of digestion and absorption nevertheless, just as our own white blood-cells have. Function always precedes structure in the world of life, and we can understand neither man nor any other living thing if we invert the true order of evolution.

But the higher the type of organism, the more does it achieve for itself in the way of an alimentary system; and though that of man is in some ways less complicated than what we find in, say, ruminating animals, yet its real complexity is incalculable, and far transcends anything that its mere anatomy can show, as the new study of diet is just beginning to teach us. That, however, is a personal matter, for personal control, and is therefore rightly dealt with under Health in this work. Here we must try to grasp the essentials of the alimentary machine as we find it in man, and, above all, to define its place in the "philosophy of the organism."

Most certainly the alimentary system exists not for itself, but for the service of the rest of the body and, ultimately, of the only organ characteristic of man, which is his brain. We eat to live; and to live to eat is essentially and surely to die. The true relation of the alimentary system to the rest of the body is daily expressed in the story of the stomach (typifying the whole system), and the revolt of the rest of the body against it, as told in the first act of Shakespeare's "Coriolanus"; and nothing demonstrates this fact so well as the essential structure of the system. True, it is significant enough that the stomach, for instance, is not itself fed by one molecule of the food it receives, but is fed from the blood in its walls just as the heart is; but even that notable fact, which is true of the entire canal, is less significant than the fact that this canal is what it is.

For it is, essentially, none other than a long tube running right through the body in such a fashion that the body is really outside it, just as the body is inside the skin. To apply a food, such as cod-liver oil, to the skin, or to apply the same food to the inside of the alimentary canal, is essentially the same thing. The process of nourishment begins with absorption—inwards through the skin in the one method of administration, outwards through the wall of the bowel in the other. The body receives no good at all until this occurs, and may starve in the midst of plenty—or with plenty in its midst—until absorption draws the food into the blood, which can then distribute it to the living tissues themselves. And, we repeat, the sheet of tissue, itself alive, through which absorption occurs is not in the least fed by the food which passes through it, but only by that which the blood brings to it upon its under surface.

All the food we receive we receive through the wall called the bowel or the wall called the skin—in an emergency—yet there is no food for either but what the blood brings back to them. There is no such thing as a skin-food; and even stomach and bowel receive nothing at all for themselves until they have first received, prepared, and distributed to and for the rest of the body. Many a patch of stomach wall has died and given rise to a gastric ulcer, though

continually flooded with food, just because the little artery supplying it from underneath has become blocked; so that it actually dies in contact with plenty. The facts, we observe, are more complete and significant even than if the stomach and bowel kept for themselves just what they needed, and handed on the rest to the body in general. On the contrary, what remains to the alimentary system is simply what is of no use either to it or to the body—what, in fact, it prevents from entering the *real* body at all.

The Astonishing Accuracy of Shakespeare's Statement of Scientific Facts

All this, somehow or other, Shakespeare knew, and makes the stomach say—

True is it, my incorporate friends (quoth he),
That I receive the general food at first,
Which you do live upon: and fit it is;
Because I am the store-house, and the shop
Of the whole body: but if you do remember,
I send it through the rivers of your blood,
Even to the court, the heart—to the seat o' the brain;
And, through the cranks and offices of man,
The strongest nerves, and small inferior veins,
From me receive that natural competency
Whereby they live. . . .
Though all at once cannot
See what I do deliver out to each;
Yet I can make my audit up, that all
From me do back receive the flour of all,
And leave me but the bran.

The fable goes back at least as far as Æsop, but Shakespeare's version, taken from Plutarch's life of Coriolanus, is far better than Plutarch's, and a writer who has repeatedly dissected and "microscoped" every inch of the alimentary system can only gasp at genius which, without any acquired knowledge at all, can pen so precisely accurate a statement of the facts. The alimentary canal, therefore, is a long tube, around and outside which the body is arranged, and this tube receives and distributes to the body what of good comes to it, leaving for itself "but the bran."

The Simplicity of the Food-Tube through which our Bodies are Fed

The alimentary system consists of this tube and its appendages. We have already seen enough of the body to guess that the appendages of any system may be very complicated, and may extend very far. We must beware here, then, of supposing that this system is isolated, notwithstanding the definiteness and the essential humbleness of its function. On the contrary, we are gradually learning that its behaviour is influenced by the chemical activity of glands that appear to have no connection with it, and we also know that, like the circulatory and respiratory systems, the alimentary system is very largely under the control of the nervous system.

But its principal appendages are unmistakable, and in essentials they are simply to be looked upon as outgrowths, or pouches, developed from the primitive tube. In another section of this work it was shown how the higher animals develop from a three-layered embryo; and now we learn that the innermost layer, called the hypoblast, of this three-layered hollow ball naturally becomes the lining of its primitive gut, or bowel, or alimentary canal. And then, for special purposes, one blind sac or another is found to be pushed out, so to say, from the wall of the canal at various points, until we find that it has quite a number of such appendages, now taking the form of glands, that produce some special substance of their own in their recesses, and send it as their special contribution to the astonishing mixture of chemicals which is called the intestinal juice.

The Elaborate Mixture of Chemicals with which our Food is Treated Internally

The whole tube is lined with glands of various kinds from end to end, each designed in one way or another to serve the alimentary function. But there are some very conspicuous outgrowths, of which the two largest are the liver and the pancreas, each of which produces a special product that is poured into the bowel, and has a notable influence upon its contents. Nevertheless, while we recognise the liver and the pancreas in this relation, we must no longer make the mistake of the older physiology, which used to look for the function of an organ, and, having found one, was content.

That view was based upon the idea that structures or organs come first and functions second. But now we realise, with all the wise men, physiologists and poets alike, who ever existed, that function comes first and makes structure. The single cell of the amœba discharges a dozen functions—it is the lung and heart and kidney and liver and brain of the amœba. Therefore we need not be astonished to find that cells in our bodies, or the collections of cells we call organs, discharge more functions than one.

In truth, physiologists are learning that they never can tell when or whether they have exhausted the functions of an organ. Anyone asked "the function of the liver"

will reply "the production of bile," and be right so far. The liver does make bile and pour it into the bowel. Similarly, the pancreas makes the pancreatic juice, and pours it into the bowel. But the liver must have at least half a dozen other functions as well as, and totally distinct from, the secretion of bile, and the pancreas has at least one, and probably two, that have nothing to do with making the pancreatic juice.

The same is true even of the walls of the alimentary canal itself. We examine them, and find that they produce, at one point or another, a digestive juice, and we are content. But further inquiry reveals novel functions for this juice, perhaps unconnected with digestion; and as we proceed we find such entirely irrelevant functions, apparently, as the production, by glands in the wall of the bowel, of vast multitudes of white blood-cells.

The Extraordinary Variety of Functions on which the Human Mouth is Employed

We proceed, then, to our study of the alimentary canal and the system of which it is the centre and oldest part, but we must beware of supposing that it necessarily confines its functions solely to digestion and absorption, and we may even note that the much-berated appendix is declared by some anatomists to be a comparatively new structure in man, not an "ancestral relic," and to have some unknown, yet possibly very useful, function of its own.

When the jaws are clenched in disease, or otherwise, we may have resort to nasal feeding, just as we may have resort to mouth breathing when the nose is blocked. But it is perfectly clear that the mouth is the entrance to the alimentary canal, as the nose is the entrance to the lungs. No doubt the case is somewhat complicated in man, because of the extraordinary development in him of the power of speech. This has meant that the mouth, tongue, and teeth, and also the muscles of the throat, or pharynx, all of which, historically and originally, are concerned with alimentation and that alone, have become largely employed for an utterly different function. All these structures were evolved for eating and drinking, for mastication, taste, adding digestive substances to the food, moistening and swallowing it. Yet, one and all, though they are essentially part of the alimentary system, and are thus found in many varieties of full perfection in dumb animals, they have now become, in man, organs of speech as well—and thus *expiration* through the mouth is normal in man. But inspiration is not, and the maxim may be repeated that, unless a man has something to say or to swallow, his mouth should be shut.

The main facts of the mouth, as regards structure and function, are familiar, and need not detain us long. Their special interest for us lies in those features which are specially characteristic of our own species. The first of these are the teeth.

Is the Modern Degeneration of Teeth a Stage in Evolutionary Progress?

Comparative anatomists have always paid special attention to the dentition of animals, not least because teeth and jaws are resistant things, and we have much fossil evidence of this character. Briefly, we note that man has twenty milk-teeth, and thirty-two styled "permanent," and that in number, and also closely in form, these are similar to the teeth of the anthropoid apes, and of no other creature. We note further that the dentition of man is unquestionably decadent or degenerate. This statement does not merely depend upon the known condition of the teeth of urban school-children, nor even upon the contrast between savage and civilised man, now existing. It depends upon the contrast between the earliest known jaws and teeth of man, many hundreds of thousands of years old, and the teeth of existing men.

The future of the teeth is an interesting matter for speculation, and we may remember, when we consider it, first, that the front teeth, incisors and canines, are of obvious value in adding to the beauty of a smile; and, second, that the incisor teeth are valuable in the pronunciation of those consonants which are called dentals, such as d and t. It need only be added that the probable explanation of showing—that is, making bare—the teeth when we smile is that this is the preliminary to playful biting of the ear, or what not, of our friend, such as we see in the case of young puppies. In certain moods, this sequel to smiling is not even now quite unnatural to mankind.

The High Importance of the Mouth in the Preparation of Food for Digestion

The teeth and tongue and lips and cheeks mechanically prepare the food for swallowing. There are no cheek-pouches in man, as in many of his not very distant allies. The mechanical preparation of the food, in such creatures as ourselves, is not all. We *can* bolt our food, as a carnivorous animal does, for its own good reasons; but the alimentary system of man is so constructed that, quite apart from any

mechanical convenience, mastication is of high importance. The fluids of the mouth not merely soften the food and give it a smooth coat for its passage to the stomach. For already we encounter no fewer than six definite and important outgrowths from the alimentary tube. These are the six salivary glands, three on each side, which produce a special secretion of their own, and pour it into the mouth. These glands are the *sublingual*, lying under the tongue, the *submaxillary*, lying under the lower jaw, or maxilla, and the *parotid*, lying in front of the ear, which last is well known for its tendency to the special infective inflammation called mumps. In structure these glands are not unlike the pancreas. Their secretion is under nervous control, and can be excited in many ways—through the eye, or the nose, for instance, as when we say that our mouth "waters."

The Instinctive Cleverness of the Organs Around the Throat in Swallowing

Saliva is markedly alkaline, and is probably an important factor in the protection of the teeth from the attacks of acids, such as are liable to be produced by microbes in the mouth. In poisonous snakes the secretion of certain of the salivary glands is modified, becoming intensely dangerous to other animals, and, instead of being led by a duct to the mouth, is led through certain teeth, hollowed for the purpose, and is squeezed through them, by muscular action, when the snake bites.

The actual digestion which occurs in the mouth is, of course, slight, for the time is so brief. Nevertheless, the food is impregnated with a digestive fluid, and the digestion really initiated in the mouth, dependent upon fluids secreted by outgrowths from the mouth, proceeds steadily in the stomach for from twenty-five to forty-five minutes after the food is swallowed.

But this swallowing deserves some attention. Only when we study its disorders, in cases of nervous disease, do we realise what an extraordinarily complex act it is. It is partly voluntary and partly reflex, large numbers of muscles being involved, including the many muscles in the tongue, those of the soft palate and the throat, and those which guard the entrance to the larynx. The food must not pass upwards into the nose, and it must be steered or shot past the larynx. It would be a serious business if one had to learn how to control it. All that we do is to pass the food to the posterior third of the tongue; and the reflex machinery does the rest.

The new-born infant has this indispensable reflex mechanism in perfect order, and it works without a hitch at once, though it has never been tested or practised with. A special centre, known as the deglutition centre, exists in the lowest part of the brain, just at its junction with the spinal cord, and links together and co-ordinates the activity of the groups of nerve-cells from which run the nerves that control all the muscles in the act of swallowing.

The Involuntary Snake-Like Action by which Food is Propelled in the Food-Tube

Difficulties are at an end once the food or drink has definitely entered the gullet. This is the much narrowed continuation of the alimentary tube, of which the first part is called the mouth, and the second the throat or pharynx. The muscular tissue of the gullet, or œsophagus, is unstriped, and its action is quite involuntary. It contracts in a rhythmical kind of wave, somewhat after the fashion of a worm or a snake, and this mode of action, which we meet throughout the entire course of the alimentary canal, and elsewhere in the body, is called peristalsis. Peristalsis or peristaltic action is, of course, the obvious means by which a muscular tube will seek to drive along anything in its interior. Even the rapid wave of contraction that runs from the base to the apex of the heart is essentially peristaltic; but we must clearly remember that the pulse in the arteries is not peristaltic, and that their muscular tissue is incapable in man of peristaltic action.

How Science has Enabled Us to Watch the Inside of the Body

Under the study of the senses we shall learn that the nerves of taste do not extend far into the throat, and not at all into the gullet. After all, taste is not primarily for our pleasure, but for decision and guidance. It would be of no use when the time for decision has gone, which is when the act of swallowing has passed beyond our control. It takes some four or five seconds for the food to be impelled through the gullet to the stomach, but fluids drop, and arrive, before the peristaltic wave has more than started.

Numberless observations upon the behaviour of the contents of the alimentary canal in this and all its other parts can, of course, be made nowadays if we take the trouble merely to include in the food some metallic salt, such as bismuth, which renders the food opaque to the Röntgen rays. Its course can then be observed just as if it were a penny. Lastly, we note

that the peristaltic wave in the œsophagus is capable of being reversed, and that this reversal is normal in animals which "chew the cud" and are called ruminants.

At its very end, the gullet passes through a special aperture in the diaphragm, or midriff, and thus leaves the chest to enter the abdomen, where it becomes continuous with the stomach. This is the most capacious part of the entire canal, existing primarily as a receptacle. It has other important functions, but is in no way necessary to life, as modern surgery has often proved.

The Essential Action of the Stomach upon our Food is that of a Churn

The essential structure of this part of the canal does not differ from what we observe elsewhere. Its outside is constituted by a coat from the peritoneum, just after the fashion we observed in the case of the heart and its pericardium. Its principal thickness is constituted by the next coat, which is muscular; and it is lined by a "mucous membrane," crammed with a variety of glands, which secrete the gastric juice.

The first function of the stomach is to be large enough to hold a meal, so that we do not need to be constantly eating. Secondly, it must mix and churn the food, which it does by a systematic employment of peristalsis, driving the food backwards and forwards steadily so long as it remains within the stomach at all. This is undoubtedly a most important function, and one is little likely to prosper if the stomach becomes flabby or dilated, so that it can no longer act as an effective churn, and sends the food onwards before its condition is suitable for the bowel.

The Stomach an Organ Not for Food-Absorption, but for Food-Preparation

For we must definitely state, as the third function of the stomach, that of guarding the bowel. Just at the point where the stomach narrows down and leads into the bowel, we find what is the strongest and thickest ring of muscular tissue in the whole course of the alimentary canal. This pylorus, as it is called, has the important function of allowing not one drop of the gastric contents to pass onwards into the bowel until they have been reduced to a proper consistence and condition. This is usually a matter of some hours, and meanwhile the gastric contents escape neither onwards nor backwards, nor yet do any of them "leak" in any appreciable quantity through the walls of the stomach. This is not an organ of absorption, but of reception, churning, protection, and digestion.

The first stage of gastric digestion, however, is in the stomach, but not of it. The alkaline mixture that left the mouth is churned to and fro by the stomach, and further softened—a process which has limits, however, for the stomach has no teeth and cannot masticate—while the special ferment of the saliva, called ptyalin, proceeds to digest the starch in the food, turning it into sugar. This is the only form of digestion that the saliva can achieve, and if there be no starch in the food, as, for instance, in the diet of an infant, which is the starch-less fluid called milk, no digestion can yet occur. On the other hand, if there be starch in the food, as in such common articles of diet as potatoes and bread, it is highly desirable that its digestion should proceed at this stage, for the stomach produces nothing that can digest starch.

After the interval named, the gastric juice begins to flow. It is very definitely acid, the acidity being due to the presence of free hydrochloric acid—a most extraordinary substance to find in such a quarter.

How the Stomach Daily Achieves Chemical Action Beyond the Power of the Chemist

It is somehow produced from the sodium chloride, or common salt of the diet, by means of the cells of special glands in the stomach wall. It is, we understand, by no means produced from the salt in the food now being digested, but from the salt in the blood, which has received it by absorption of previous meals from the bowel. Sodium chloride is an exceedingly firm compound, and the chemist who was asked to split it, and produce hydrochloric acid, in his laboratory, at the temperature of the body, would reply that such a feat was wildly impossible. And yet the body does it every day.

The digestion of starch by ptyalin ceases instantly when the hydrochloric acid is produced, for the gastric contents now become markedly acid, and ptyalin can only act in an alkaline medium. But we are to note that, in this as in many other cases, there is a natural rhythm in the chemistry of the body. The students of drugs know that the fashion in which to call forth an acid secretion is to apply an alkali, and *vice versâ*. Just so, the alkaline saliva is the natural excitant of the acid gastric juice, which means that the more honestly we chew, the better will be performed, not merely the first, but also the second stage of gastric digestion. And, further, it is the acidity of the gastric contents, when poured into the bowel, that

stimulates the production of the intestinal secretion and of the pancreatic juice, both of which are markedly alkaline. Thus we see that the whole series of digestive processes is largely an interdependent sequence, and that it is our business rightly to start that sequence by proper mastication.

The characteristic ferment of the stomach is called pepsin. The action of all ferments is specific, not general. This ferment can digest proteins, and proteins alone. It requires the aid of hydrochloric acid, but that acid is not the actual digestive agent. The peptic digestion of the proteins of the food, assuming such to be present, may occupy several hours before the pylorus considers, so to say, that the gastric contents are fit for reception by the bowel. But this digestion is seldom really complete, and is of small importance compared with the digestive processes in the bowel itself.

It is merely a popular delusion that digestion is essentially an affair of the stomach, a fact which becomes clear enough if we note, first, that the stomach has no action of its own upon starchy foods; second, that it has no action whatever upon fats in the food; and, third, that even its special ferment, pepsin, is weak and inadequate compared with the ferment of proteins which the food is now about to encounter.

A Part of our Body that We should be Much Better Without

The next part of the alimentary canal is called the bowel, in general, and may be divided into the large and small bowel, or gut, or intestine. Of these, the small intestine comes first, and its coils occupy several yards of the length of the whole canal, but the large gut, which succeeds it, is of larger calibre, though much shorter and vastly less important. The large gut follows upon the small gut, at a definite spot in the right-hand lower corner of the abdominal cavity, and close to the junction we find the curious little blind sac called the *appendix vermiformis*—or "worm-like appendage" to the bowel. The large bowel ends in a straight portion called the rectum, by which the remains of the intestinal contents are conducted from the body. No more need here be said about the large intestine, except that Prof. Metchnikoff and others have adduced powerful arguments in favour of the view that this is a very nearly superfluous, if not dangerous, part of the body.

Very different is the case in many of the lower animals, whose diet is of a different kind. But in us, though the large intestine is far smaller than in many animals, it is probably more than large enough. No digestion occurs in it. The quantity of waste matter in our diet is relatively very small—often, apparently, too small even to stimulate the large bowel to peristaltic action. Further, it has become the home of microbes, which are only too apt to flourish there beyond all safe limits, and produce poisons which enter the blood and injure us. All this question, however, so closely concerns health, and is so largely under our own control, that it must be discussed elsewhere. It issues in the commonest malady of civilised life, which is constipation.

The Stomach as the Slaughterhouse of the Enemies of the Body

Meanwhile, we have the small bowel to deal with. We note, first, that it is the most delicate, the most skilful, and the most versatile part of the whole alimentary canal. As such it requires protection, and we have already seen how the pylorus of the stomach stands at guard over the entrance to the bowel. But the stomach does more. Hydrochloric acid is a powerful antiseptic. Numerous observations on mankind and the lower animals, and not least the new work done by the Tuberculosis Commission in this country, and work on the same disease abroad, show that the stomach must have great powers of killing microbes. It does not always succeed; but the healthy stomach, duly producing a sufficiency of hydrochloric acid, must kill innumerable dangerous microbes, and every doctor knows the lamentable consequences when this precious acid is not produced. Normally, the upshot must be that the chyme, the name given to the food as it enters the bowel, must be not merely churned, and in part digested, but also very largely sterilised, to the immense advantage of the bowel, and of the body.

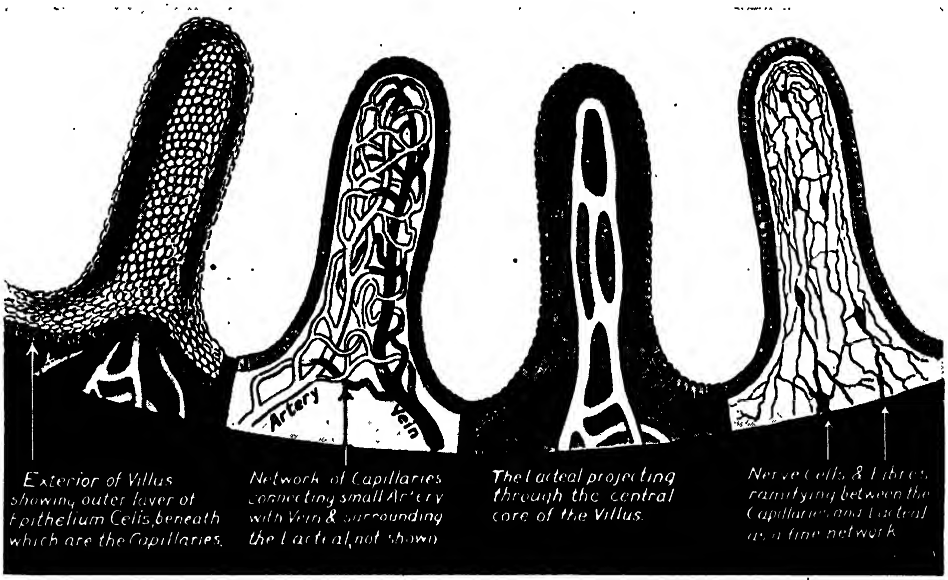
Popular Misconceptions Removed as to Where Digestion is Actually Carried On

The small bowel produces digestive ferments of its own. As our knowledge of this subject increases, we find that where we thought there was one ferment there are really half a dozen. But probably, even so, the bile from the liver, and especially the pancreatic juice, are more important than the materials produced by the bowel itself. These special secretions must be considered further when we come to look at the glands of the body. Meanwhile, we note that, in the upshot, digestion occurs in the upper part of the bowel. The digestion of starch into sugar, by

means of the saliva, begun in the mouth, and continued in the stomach, is carried out far more efficiently in the bowel, by means of one of the ferments in the pancreatic juice. The digestion of proteins by the gastric juice, begun rather than effected in the stomach, is done thoroughly in the bowel, not by means of pepsin, which cannot act at all in the alkaline fluids of the bowel, but by means of another constituent of the pancreatic juice. A third constituent of this juice digests the fats of the food, which have hitherto undergone no digestion at all.

All this is done in the bowel, though only subordinately by it. Its own feat is of a wholly different kind, for which, however, all that has gone before is only a preparation. The small bowel is the ***organ of absorption.*** We live neither by what we swallow nor yet by what we digest, but solely by what we absorb. This process is not mechanical, but vital—so palpably vital that not even in the dull stupidity of the materialistic creed of the nineteenth century did physiologists suppose that the process of absorption is a mere leakage through the wall of the bowel into the blood. The characteristic of the wall of the small bowel is that it is covered with millions of tiny, glove-finger-like projections called the intestinal villi. Each villus is covered with a single layer of deep, nucleated cells. Within it are two sets of vessels—a loop of capillary blood-vessels, and a corresponding supply of lymph-vessels, called lacteals. The cells of the villus recompose the digested fat in the bowel (for it has been turned into strange things, such as soap and glycerine), and pass it into the lacteals. These carry it away, and after a meal their contents give them a milky appearance, from which they derive their name. They are really just lymphatic vessels, bearing this special milk-like burden, called chyle, from the bowel.

The other valuable constituents of the intestinal contents are absorbed by the cells covering the villus, and are thence passed into the blood. The fact is easily stated. What happens is, however, beyond our utmost powers to explain. The cells of the villus take the materials into which the proteins of the food have been broken up by digestion, and build them into new proteins, human and only human, which then become the normal proteins of human blood. These were not in the food, save only in primitive feasts where human blood was consumed; but they were constructed, for the first time, by these cells, and by them we live. Any other proteins but those of human milk, injected directly into the blood, are immediately removed as poisonous, which they really are. That is what we really mean by "intestinal absorption," and with this achievement our statement of the alimentary system properly closes.



HIGHLY MAGNIFIED DIAGRAMS OF THE SMALL PROJECTIONS IN THE ALIMENTARY CANAL, BY MEANS OF WHICH THE NUTRITIOUS ELEMENTS IN THE FOOD ARE ABSORBED BY THE BLOOD

DECORATION THE REASON FOR DRESS

THE ELABORATE AND ORNAMENTAL COSTUME OF NATIVE CHIEFS OF CENTRAL AFRICA

This photograph and that on page 1435 are by Messrs. Underwood & Underwood, London

PRINCIPLES OF CLOTHING

The Essential Purposes Served by Clothing and the Qualities Needed for such Service

DO WE SACRIFICE USE TO DECORATION?

PLAINLY we must begin by asking why, in point of fact, we do clothe ourselves, and why we should clothe ourselves. We shall soon see that there are various ends in view, some of which may, at any moment, directly conflict with others—as any walk abroad, in any street anywhere, will instantly demonstrate. But in this work our business is scientific, and in this section hygienic. We cannot, therefore, consider the problems of art, of political economy, or of conventional morality, which are intermingled with the hygiene of clothing.

But, clearly, we put things upon our person for three distinct purposes—decoration, decency, and health. This simple analysis alone suffices for a volume, or volumes, as Carlyle's "Sartor Resartus" illustrates. But for our purpose we need note only two or three points of general interest before we confine ourselves to the third and last use of clothing.

Our ancestors and allies, such as the monkeys and apes, need no clothing, because they are already clothed. It is one of the historical and largely incomprehensible facts of man's body that it has become almost wholly denuded. His is a naked skin, throughout life, like that of the new-born, or very young, of many of the lower animals which are well clothed with fur or feathers in later life. There, however, is the unexplained but interesting fact.

It is, in some ways, less remarkable than might appear. If we imagine primitive man to have been evolved in the tropics, but among trees, we find a combination of warmth and shade which is, after all, just the best for nakedness. The real problem for man, so far as his skin is concerned, begins when he betakes himself, thus externally fitted only for tropical shade, out into the open, and then, North and South, even to the neighbourhood of the Poles. Consider the skin of the seal and the Polar bear and Arctic fox, and compare it with the skin of the Eskimo! That single but sensational comparison will teach us what a conqueror is man.

Yet the historical evidence seems clear that the earliest assumption of clothing by man was for purposes of decoration. At this time he was living in warmth enough, and could find shade in the heat of the day; while we must remember that it is a common thing to see a shaven head, in India, exposed to the full glare of the sun. But the instinct towards personal decoration is irresistible; and so we find that decoration precedes dress, or use, in the history of clothes, a fact which Herbert Spencer quotes, at the beginning of his great book on "Education," in order to suggest that our theory of education is the same, beginning with mere decorative attainments, and only slowly learning that the first business of education is for the uses of Life.

In our own day, the complication remains; and the hygienist is compelled to fulminate against practices in the matter of clothing which grossly subordinate health to decoration, or to what is thought to be such. The teacher of these things, from the hygienic standpoint, awaits and expects the day when there shall be an alliance between the hygienists and the artists, the lovers of life and the lovers of beauty, so as to teach the world that the clothing which best serves health is, on the whole, that which also best serves the interest of grace and beauty.

Still less need be said regarding the relation of clothing to our ideas of decency. But all comparative study whatever, all observation of children and natural people and the insane, and all psychological probability, contradict the view that the sense of personal decency led to the adoption of clothes, as in the story of Genesis. There is

no room for doubt that the reverse was the fact. We wear clothes for decoration or health, and then to be without them comes to be regarded, by ourselves and others, as improper or indecent. But we need only consider the varying practices of "morning dress" and "evening dress," of gymnastic dress and bathing-dress, even within the limits of one nation, to see how conventional—though not therefore necessarily quite useless or absurd—these ideas are. If the hygienist found himself compelled in the interests of health to condemn the present practice, and to make recommendations which public opinion would regard as indecent—being really, of course, neither decent nor indecent. but merely different from what we now think decent—his task might well appal the bravest, but there is no such need. It is not necessary to demand "bifurcated garments" for women, or, rather, it is not necessary to condemn the wearing of a light skirt over such garments; and if the hygienist does see good cause to demand that skirts shall be a few inches shorter than used to be thought proper, fortunately modern fashion and sports have performed his task for him.

We proceed, then, with our business, which is solely the hygienic or protective function of clothes.

The First Use of Clothes—Protection Against Cold and Against Heat

This, however, is not quite simple in itself, for there are varying requirements, which cannot be realised until we begin to think about them, and which ultimately depend upon the strange evolution of the body of man, strange and almost reckless, which has been described in another section of this work. Very generally, we require clothes, first, in order to keep us warm. There are times and places that furnish exceptions to this rule, but it is almost constant, and obviously corresponds to the unparalleled exposure and defencelessness of the skin of man.

This exposure cuts both ways. It threatens us with cold, and it threatens us also with heat. Not a hot state of the air, however, but only radiant heat, is what our naked skins have to fear. So far as excessive heat of the air is concerned, clothes can only make our case worse. But they may be indispensable for the protection of our skin from the shafts of direct sunlight. This, as we shall learn, especially applies to the head and the back of the neck, and the backbone, but sunburn is possible anywhere.

In this part of the world we have so little strong sunlight that, when it does come, we are the less able to cope with it. We are probably further exposed owing to the lack of much pigment in the skin; and, lastly we have to remember that many of us soon tend to lose the natural protection of the skull and brain from direct sunlight, which has otherwise been saved from the general denudation of the body of man.

People Whose Clothes Keep Them Clean, and Those Whose Clothes Keep Them Dirty

But these two functions by no means exhaust the protective or hygienic function of clothing. Two more remain, both of high importance. Clothes protect from dirt, or should be used to do so. No doubt it is true that, only too often, we use clothes much after the fashion in which the domestic filter was wont to be used—not merely to catch dirt, but also to keep it—not to say *grow* it, for the deadliest dirt is alive, when caught. The danger of dirty clothing, by day and by night, must later concern us. It is to be met by proper attention to the details of clothing, and by personal cleanliness. But if we know how to clothe ourselves, and attend to our clothing, our clothes keep us clean, and protect us alike from dead and from living dirt. There is no third course, however; and people may undoubtedly be divided into those whose clothes keep them clean and those whose clothes keep them dirty.

The Use of Clothes in Protecting Us from Mechanical Injury—Particularly the Feet

Fourth, and last, certain parts of our attire perform valuable functions in protecting parts of the body from mechanical injury. A special instance of this is the helmet of the fireman or the policeman, which undoubtedly supplements the skull in the all-important task of affording mechanical protection to the brain within. The occasional use of a hard and rigid piece of clothing for such purposes, and in such a place, has little to be said against it.

Altogether different, as we shall see, is the employment of any such rigid protection for the trunk of the body, and most especially for its upper portion, which must necessarily expand and contract if we are to live. But at the lower end of the body clothing may constantly serve the purpose of mechanical protection for the strangely naked and ill-protected feet of man—man the traveller, the pioneer, the path-maker of the living world. We have seen elsewhere how remarkable are the feet of man from the evolutionary and mechanical point of

view. They always and everywhere are advantaged by clothing, but we shall find that the problem of helping them without hurting them is almost insoluble.

Such, then, are the four protective or hygienic functions of clothing—to keep us warm, to protect the skin from direct sunlight, to ward off dirt, and to protect such ill-protected structures as the feet from mechanical injury. And now we may lay down the first principles which should be obeyed in meeting these indications. Once we grasp them—but not till then—we are fit to face the details of the clothing, inner and outer, of the various parts of the body.

We said, first, that clothes keep us warm, and the phrase is accurate. We may be warmed from without by sunlight, hot bottles, or fires, or radiators, but none of these would save us if we did not keep ourselves warm, as we do. No clothes produce any heat whatever. They merely keep us warm by preventing the outflow of heat.

The Object of Clothes—to Keep in the Warmth, not to Keep Out the Cold

Heat, of course, is a physical reality, but there is no such thing as cold, which is merely the absence, or rather the relative absence, of heat. We talk colloquially of keeping out the cold, but there is no such thing to keep out; and our language is no more accurate than that of the child who broke the air-pump "to let out the vacuum." "Keeping out the cold" is really keeping in the heat; and thus what we call warm clothes are not at all clothes warmer than their surroundings, for they are indeed of just the same temperature as their surroundings, but rather clothes which are bad conductors of heat, and so keep in our warmth. We need only remind ourselves that flannel is used alike to keep babies warm and to keep ice cold.

Since clothes constantly tend to retard the flow of heat from the body, and since the body must never rise beyond a certain limited temperature—and would, indeed, soon boil if its heat were not taken away from it—plainly there must be a relation between the amount of clothing one wears and the amount of combustion that occurs in the body. One should expect the people who produce least heat to wear, on the average, the most clothing, and that is quite obviously the case. On the whole, the lithe, active, mobile, energetic people wear less clothing than people of the opposite habit, because they are producing more heat, and must not too much retard its outflow.

This interesting point raises another—the connection between diet and dress, between food and clothing. The future must work it out, and decide the best course for health. But, plainly, the more we obstruct the outflow of heat from the body by clothing, the less food of the fuel type do we require. Probably much of the controversy between people, scientific and unscientific, as to diet would be resolved if they made their observations under conditions of constant clothing and external temperature. Now, once we grant that there must necessarily be this relation between diet and dress, our problem for health is not solved, but merely stated.

The Controversial Claims of Light Clothing and of Heavy Clothing

There are arguments in favour of light and in favour of heavy clothing. Good, warm clothing, as we call it, must tend towards economy in the matter of the fuel-foods; and economy in diet is a matter of national, and often of personal, importance. On the other hand, a rapid production and disposal of energy in the body may tend towards a more active and enjoyable life; and it may also involve greater protection against microbes. We should remember that the relation between under-feeding and susceptibility to tuberculosis seems to be beyond challenge. On such grounds, one should argue for a more liberal supply of the fuel-foods, of which sugar is the type, but which include sugar, starch, and fat; and for a rather light supply of clothing, so that one may not be burdened by the larger supply of heat that one is producing. This last is the writer's own belief, which he offers to the reader, but with the warning that we are yet without proof on this point.

The One Case in which Clothing Should Unquestionably be Warm and Ample

But critical reception of such advice will suggest an all-important proviso. If one is to adopt the plan of light clothing, which involves the consumption, certainly not of the ordinary grossly excessive diet, but of a larger diet than would otherwise be required, plainly we must assume that the organs of excretion—or, to be precise, the kidneys—are healthy. For the more one eats, the greater is the work inevitably thrown upon the kidneys; the more furious the furnace, the more abundant the ash. Hence a simple and cardinal rule for all cases where the kidneys are either diseased or somewhat unequal to their work, or liable, with advancing years, and with the warning of rather rigid arteries, when felt at the wrist, to become so.

Most evidently, the indication, as doctors say, in all such cases, must be to lighten the work of the ill or threatened organs; and one way of doing so is to clothe warmly.

This has a double action, and we must recognise both parts of it. First, as we have suggested, it facilitates a reduction of the diet, by better maintaining the temperature of the body. Second, the warm clothing encourages the action of the skin, which is itself an organ of excretion, and which can thus, to a small but valuable extent, bear some of the burden of the kidneys. Thus, while we cannot determine the best course for health with absolute certainty, though we incline to the view that clothing should be light, at any rate for the young and those in the prime of life, we have no doubt at all that, where the state of the kidneys is at all in question, clothing should be warm and ample.

Let us pass now to another of the first principles of clothing—one of universal application, though constantly outraged in practice. It is that clothing should be loose. The body was not made for clothes, but clothes for the body. Nature has not meant or expected the movements of the body as a whole, or of any of its parts upon each other, to be restricted by anything more than the atmospheric pressure, which bears equally on every part, and thus incommodes none. Thus, directly we assume clothing we run the risk of pressure or restriction of movement.

A tight hat or a tight collar must affect the movement of blood in the veins, especially of the scalp and the neck. Veins, as a rule, are nearer the surface than arteries, they have much thinner walls, and the pressure of the blood within them is much lower. For these three reasons it follows that veins are specially subject to be affected by external pressure. In such a case as either of those quoted, the

GRACE AND SIMPLICITY IN COSTUME

From the painting entitled "The Golden Stair," by Sir E. Burne-Jones, by permission of Mr. F. Hollyer.

ffect must tend towards congestion of the calp with venous blood that is, with used und useless blood; and we may reasonably argue that this must tend towards malnutrition of the scalp, and possible baldness or greyness of the hair. Similarly, the pressure of boots and shoes more or less leforms the toes of everyone who wears hem. The only perfect feet are those of he infant or the wholly bedridden invalid. Continuous pressure upon the skin of the oes would cause an ulcer; the intermittent pressure of foot-gear causes corns. The joints are also deformed, the joint of he great toe being bent outwards in everybody. This is the best-abused joint in the body, a fact which suffices to explain the but the tight clothing of too many women's waists has compelled them to employ a compensatory action of the ribs, since the diaphragm was so hampered, and has deceived the physiologists.

If the pressure of clothing extends to the walls of the abdomen, harm is done there also. The abdominal wall ought to be able to hold itself upright, to move freely in walking and breathing, and to encourage the movements of the bowel within it. If it does not do so, constipation is encouraged. But it will not do so if it be supported or hampered from without, for every living thing and every part of every living thing that is meant for use degenerates if it be not used.

THE OVER-ELABORATION OF COSTUME IN THE POMPADOUR PERIOD IN FRANCE

fact that gout almost invariably chooses it as the first victim.

Yet again, the pressure of a garter interferes with the upward flow of blood through the veins of the leg, and helps to make them varicose. The pressure of anything upon the chest, which should above all be left free, interferes with the natural expansion of the lungs, opposes full aeration of the blood, and predisposes to consumption. So true is this that, until recent years, physiologists taught that there is a natural difference between the sexes in the matter of breathing, men breathing mainly with the diaphragm or midriff, and women mainly with the ribs. There is no sexual difference in respiration whatever;

Therefore the rule is that, from top to toe, all pressure of clothing is undesirable. It cannot be wholly avoided, owing to the weight of one's clothes, but it must be kept to a minimum, it must be evenly distributed, and should be largely borne by the shoulders, which can bear it best. And, on closer observation, we find that the outside pressure of clothing may simply starve a limb or other part by depriving it of its blood-supply. This is the secret, largely, of the now obsolete Chinese method of limiting the growth of women's feet. The young feet are so tightly bandaged that they are starved and dwarfed. Rash bandaging may starve a limb, so that it requires amputation.

Many people suffer from cold hands or feet because they ignore the rule that clothing should be loose. If a glove or a boot be very tight, the foot or hand is starved of blood; but the extremities of the body are maintained in temperature by the blood, making practically no heat for themselves. The proper way in which to keep one's hands and feet warm is from within, and this can only be done if we allow the warm blood to enter them freely. All this is very important reading for people who are liable to chilblains.

The Greater Warmth of Loose Clothing Owing to Its Imprisonment of Air

A motionless or slowly moving gas is a bad conductor of heat. We all know the difference between still air and air in motion, which we call a draught or a wind, as regards their cooling effect. It follows that our clothes keep us warm not merely in themselves, but because they partly imprison a good deal of air within them. This, of course, can only be the case if one's clothing is loose. A given amount of a given material and texture is warmer as a loose garment than as a tight one, simply because it imprisons, as a loose garment, a good deal of air, and we are thus clothed with air as well as with cloth. Other things being equal, the warmest clothing would, indeed, be air-tight clothing; but we all know that it does not do to wear a tight waterproof, which is largely air-tight, habitually, and indeed we should see to it that our clothes are ventilated as well as our rooms. Two or three layers of loose clothing will partly imprison a quantity of air between them, and furnish as good a kind of clothing as can be.

The Lesson of Lightness with Warmth to be Learnt From the Coats of Animals

The next general question is as to the material of clothing. Here we may take a lesson from our animal allies; and we soon learn that hair is the natural and characteristic clothing of a mammal, in such forms, for instance, as the fur of the rabbit or cat or seal, and the wool of the sheep. Everywhere, therefore, where warmth is desired, we adopt such materials. But it is an utter delusion to suppose that material is everything, as such. On the contrary, the important fact about the natural material is its admirable and, unfortunately, inimitable texture. The coat of the sheep is not merely warm, but it is light, highly absorbent, and perfectly ventilated.

Very often we take this exquisite material, convert it into a dense, inflexible, non-absorbent texture, and suppose it will necessarily make perfect clothing because it is still made of wool—which is absurd.

No doubt the sheep has a considerable advantage. Its clothing grows out of its skin, needs neither safety-pins, tapes, nor buttons, and does not need to be woven in order to hold together. The sheep's advantage can be realised if we consider the case of a man wearing a sheepskin coat. He is wearing not only the sheep's clothing, but also the sheep's skin, which he puts on outside his own. Nevertheless, it is possible to weave wool into light, warm, air-holding textures which still retain some of the properties of the natural coat. And this must be seen to, for there is another essential of clothing—no less than that it be loose.

It must be absorbent. The skin, as we have seen, is an organ of excretion; and our problem is to interfere, to some degree, with its output of heat, while not interfering at all with its output of dirt.

The Need for All Clothing To Be in a High Degree Absorbent

Therefore, at the very least, the changed layer of clothing next the skin must be absorbent, and this is the more necessary the more complete and close the clothing be. The skin needs no absorbent arrangement if it be left alone, as the unclothed face suffices to prove; the problem only arises when we start to clothe it. And the great virtue of wool next the skin, when it is of suitable texture, is that it is highly absorbent.

When it is of unsuitable texture, its virtue goes out of it. This is one of the numerous grounds on which we are bound to condemn the old-fashioned "chest-protector." It is really a chest-weakener, by its interference with the functions of the skin of the chest. It dates from times when we did not understand the essential nature of the diseases of the chest, such as consumption. Of course, the chest should be warmly enough clad. But the clothing should be general, and not confined to the front wall of the chest, over the interval between the two lungs, which is the spot chiefly covered by most chest-protectors.

The lungs lie more under the back than the front of the chest. No doctor, of course, has really examined the lungs, for consumption or anything else, who does not examine them behind as well as in front. Yet even when the "chest-protector" has a back as well as a front piece, the back chiefly covers the spine and the large muscles near the spine, the most exposed parts of the lungs being neglected by it. The lungs are

infected through the mouth and nose; and the "chest-protector" no more keeps out microbes than the bricks of the side-wall prevent burglars from entering by the door or windows of your house. The real chest-protector is a properly used and usable nose. But, further, the "chest-protector" is almost always made of practically non-absorbent flannel; and, pray, how often is it washed? Let no sensible reader of these ages patronise such absurdities.

Some people cannot wear wool next the kin, for it causes hem too much dis-omfort, and may ven produce what s called a "flannel-ash." Such people iust, nevertheless, vear sufficiently ab-orbent clothing ext the skin; and n recent years nanufacturers have ompeted in the roduction of a irge variety of nderclothing made f silk, linen, cotton, r combinations of hese, which are quite absorbent, and freely to be recommended to those who find them warm enough. For it is certainly not necessary for health to wear wool next one's skin if one be otherwise kept warm enough, and if what one does wear be absorbent.

A CHINESE WOMAN OF HIGH RANK, SHOWING THE BOUND UP FEET

What this question of absorption really means we discover when we are told that the average man disposes of about twenty-five ounces of water by his skin every day, together with various gases and a good deal of oil. This simple physiological fact suggests that one should chiefly rely upon the outer clothing for the business of maintaining warmth, while the underclothing should usually consist of materials that are absorbent, cheap, very easily, frequently, and thoroughly washable. It would be only too easy to prove that our ancestors' standard of cleanliness was what we should now regard as disgusting. Only the very wealthy could afford to be clad in "fine linen." But nowadays cotton is available, and greatly serves the good cause of personal cleanliness for the many.

Let us not too readily decry the cheapness and lack of durability of much modern clothing. It is by no means certain that we want clothes to last so very long, especially the clothing nearest one's skin. "It is what cometh out of a man that defileth." From the hygienic point of view there is a pretty large fraction of the clothing now in these islands that is only fit to be burnt — or, at least, baked. "Cheap and nasty" does not apply to clothes at all, and ideally they should be literally ephemeral, lasting for one day only. No doubt that is a counsel of perfection, but even washing has its risk for the washer, and ordinary washing is far from trustworthy as a steriliser. The ideal, so far as personal clothing is concerned, is certainly the Japanese handkerchief—here to-day, and gone to-morrow.

Such, in outline, are the first principles of clothing, considered only from the standpoint of hygiene. Its four distinct functions must be duly taken into account; and, in considering the needs of each part of the body, we are to remember that all clothing must try, as far as possible, to conform to the principles illustrated in the perfect coats of so many of the lower animals, coats which are warm, yet perfectly ventilated; close, yet never tight; highly absorbent, yet easily cleansed. It is only by paying attention to these things that dress can be brought into its proper relation to health.

Sir W. H. Perkin discovered aniline dyes in coal when he was a lad of eighteen, mauve being the first colour he secured. Enormous industries are built on the scientific foundations he laid down
This portrait is reproduced by the courtesy of the artist, Mr. A. S. Cope, R.A.

MODERN TREASURE TROVE

How Cheaper Power is Being Won and Untold Riches are Extracted from Waste

VICTORIES OF ENGINEERS AND CHEMISTS

As civilisation advances, population presses on the means of subsistence, and a sense of the folly and sinfulness of waste is awakened. There is no waste in Nature.

That there should be any waste at all in any industry is now regarded as a reflection both on the men of science and on the captains of industry. Not only is the fact of the waste itself mournful and reprehensible, but the disposal of the wasted products themselves is costly and often offensive.

Waste may be very broadly grouped under two heads. One is that of power agencies, the other the by-products thrown out in the preparation of primary products. The waste gases from iron-furnaces, the coke from gas-retorts, the refuse of cities, and the inferior fuels are familiar examples of the first. Illustrations of the second are the by-products and wastes of chemical and other industries which are not sources of power.

Heat is the primal agent of Power—heat derived from coal and held in the grip of steam; heat stored up in gas derived from coal, and oil, and waste fuel; and that surplus heat much of which passes the wit of man to utilise. Although the amount of coal that is now used to yield a horse-power is only from one-sixth to one-eighth of the quantity employed a hundred years ago, the waste is still appalling.

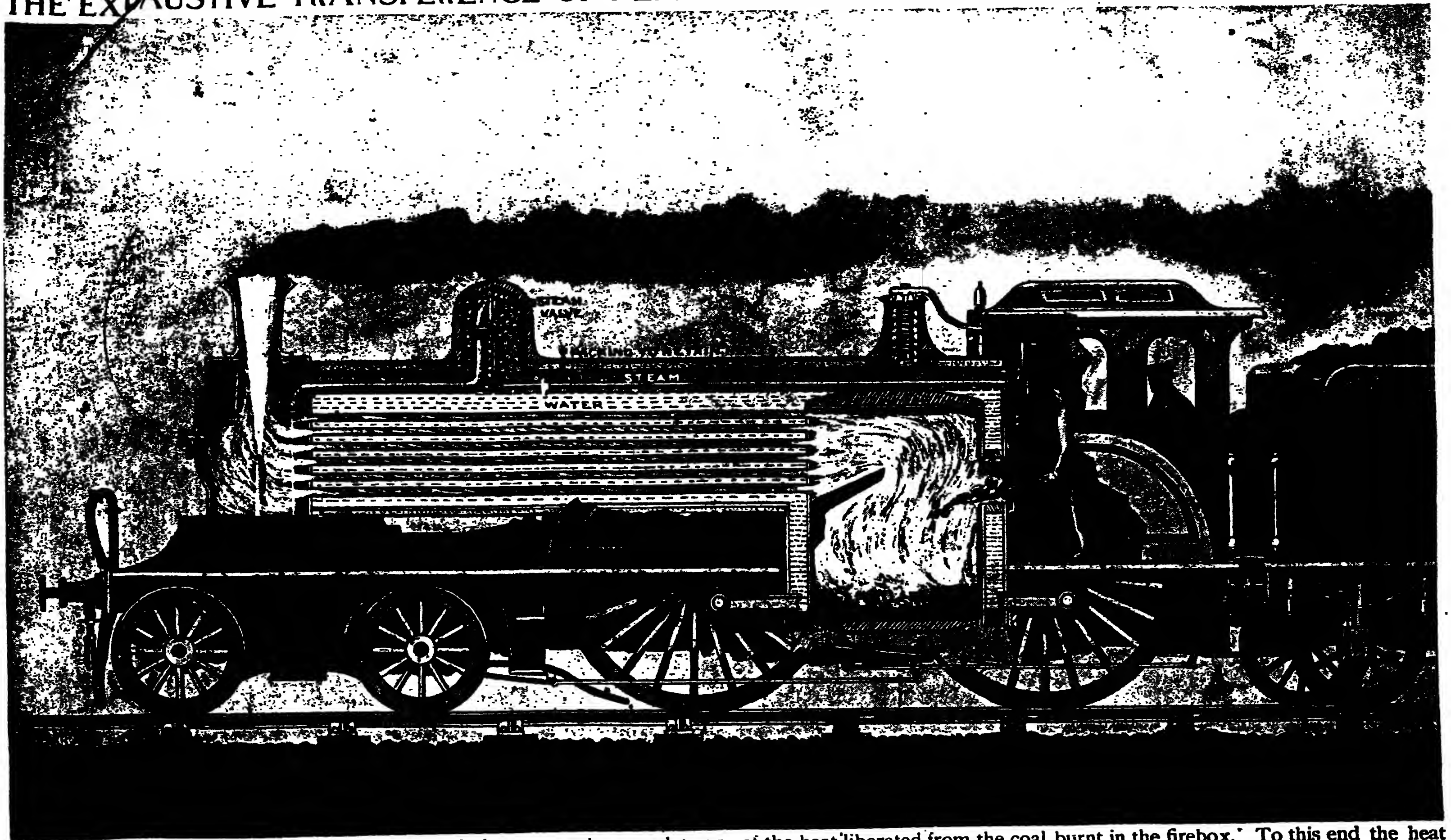
Take the boilers first. The locomotive and many other land and marine boilers built on the locomotive type have from one thousand to two thousand small fire-tubes going from the fire-box to the chimney, and passing through the water. The object of this, as of many other similar devices in boiler engineering, is to delay the escape of the waste heat from the fire, and make it yield as much as possible up to the water, and so generate steam. In another kind of boiler, the "Lancashire," used much on land, when the hot gases from the furnaces have passed through the boiler to the back end, they are brought along to the front again through flues situated at the bottom of the boiler, outside it, and thence they are returned once more to the hinder end by way of side-flues. This trebles their period of contact with the water within the boiler. Many boilers also have, in addition, cross-flues which carry the hot gases again through the water-space.

And yet again, many of these boilers are provided with a "Green's Economiser," by which the waste heat is intercepted on its way to the chimney and is forced to heat the feed-water for the boiler. The gases are led around nests of hundreds of pipes through which the water supply is passing, so raising its temperature up to as much as 300° Fahr. In this way a saving in fuel of from 15 to 20 per cent. is effected, because the coal in the boiler has not to do the preliminary heating up of cold feed-water.

The same kind of economy is effected in the numerous "heaters" which raise the temperature of feed-water supply to boilers by means of steam that has been exhausted from the engines or other sources. This is caused to pass through the heaters on the way to the chimney. For each 100° of temperature added thus to feed-water above the normal temperature, a saving of about 9 per cent. in fuel results.

In the engines themselves the same grudging tactics are followed, and the steam is forced to yield up its heat in successive stages from pressures as high as ten or twelve atmospheres to as low sometimes as the atmospheric pressure. In compound engines it is used twice over, in triple and quadruple expansion engines three and four times over respectively. At each stage it expands, yielding up more of its heat with

THE EXHAUSTIVE TRANSFERENCE OF HEAT FROM COAL TO WATER IN THE LOCOMOTIVE



The elimination of waste in the locomotive depends largely on the complete use of the heat liberated from the coal burnt in the firebox. To this end the heat passes through a great number of small tubes—represented for clearness in the diagram drawing above by only six—which are surrounded by water. The passage of the heat is thus delayed until a large percentage of it has been transferred to the adjacent water

lessened pressure, until finally it is conducted into a condenser, in which it heats the boiler feed-water, and is itself condensed into hot water to supply the boiler.

Many thousands of pounds are thrown into the air every year in the shape of steam which, having done its work in engines, is sent directly up the chimney, instead of being utilised in the ways just mentioned. This waste occurs largely in factories, and in electric-power stations. Yet in the same factories a separate heating apparatus for the workshops will often be found installed, quite neglectful of the fact that the steam thus wasted would warm the buildings efficiently, or heat water, and cost nothing.

The Economical System of Wholesale Heating of Houses in America

In America, where the winters are cold, there are two hundred central stations which supply only heat to warm public buildings, factories, and private houses. We have nothing of the kind here, but each individual firm or institution lays down its own plant at enormous aggregate cost, while thousands of tons of exhaust steam are discharged into the atmosphere.

All the millions of tons of steel now made in the world in the open-hearth furnaces are melted to a large extent by the waste heat in the furnaces themselves. The method is almost ridiculously simple. It just consists in the conduction of the waste gases from the furnace, as they go on their way to the chimney, through a wall of open or "chequered" brickwork. These gases make the brickwork extremely hot, rendering up to it nearly all their heat before they are discharged into the chimney. Then at that stage the incoming cold gas and air required for combustion in the furnace are brought into it through the hot brickwork, becoming, of course, highly heated on their way. The obvious result is an immense saving in fuel.

The Use Abroad of Directly Driven Gas-Engines Using Gas Waste

About a dozen years ago Belgian and German engineers showed the way to a better system of using waste gases—to drive big gas-engines direct instead of to raise steam in boilers. Although the Continental engineers have adopted this practice more enthusiastically than ourselves, the inception of the idea was due to an Englishman, the late Mr. B. H. Thwaite, who, in 1893, with Mr. Riley, fitted out a plant at Wishaw. The Cockerill Company, of Seraing, near Liége, in Belgium, built the first very big engine, one of 600 horse-power, which excited great interest at the Paris Exhibition in 1900. During the ten years following, gas-engines have been built in increasing sizes, until now a single engine may equal the power of 6000 horses.

An ordinary blast-furnace will not only supply enough waste heat to drive its own powerful blowing-engines, but will yield a surplus of from 9000 to 10,000 horse-power per year. The United States Steel Corporation saves about a million tons of coal per annum by the adoption of this method, for it has installed 250,000 horse-power of gas-driven engines and electric generators, actuated by waste gases alone.

Germany now produces 13,000,000 tons of pig iron annually. For each ton, 150,000 cubic feet of gas are given out. At the present time there are in Germany about 300 big gas-engines working on blast-furnace waste gas in forty-one iron and steel works, with a yield of 650,000 horse-power.

Slags, which are waste from the blast-furnaces, have different uses, as they differ from one another in chemical structure. In America and Germany certain slags are used largely for Portland cement, of which about twelve million barrels are now made annually from blast-furnaces in the Chicago district.

Varied Uses to which Furnace Slag is Now Profitably Devoted

There are four great cement works in Germany manufacturing this product. Many slags require the addition of only 10 to 20 per cent. of the real Portland cement and a small quantity of gypsum to make a cement as good as, and, for use in sea water, better than those that are made wholly of Portland cement.

Slag made from the basic Bessemer process is now always ground in mills and used as manure. It owes its value to its phosphorus, which is fluxed off from the iron ore. The higher the phosphorus, the more valuable is the slag. And it so happens that the presence of phosphorus even in small quantities makes bad iron. So that in removing practically all the phosphorus from the iron in the converter, the steelmaker increases the market value of the slag.

Another of the important utilities of slag is in the preparation of non-conducting coverings to prevent radiation of heat from steam-pipes and cold storage chambers, etc. A jet of steam is directed on the stream of molten slag as it flows from the furnace. Many fine particles or "shots" of slag are thus blown out from the mass, which draw fine, glass-like threads after them. These are sucked through a tube

and deposited on a sieve. The wool thus produced is one of the very best obstacles to the transmission of heat, being better than asbestos, besides which it has some advantages not possessed by many non-conductors. It is as fire-resisting as asbestos. It will not become converted into a solid mass by vibration. Moisture does not affect it, which is not the case with wool and hair and some other substances used for "lagging."

The Challengers to the Reign of Coal as a Power Fuel

Slag is used with lime for making bricks. They are more expensive than common bricks, but are much harder and better able to resist crushing; while they do not absorb moisture, and thus houses built of them can never be damp. At Landore, in Wales, there are large works devoted to the manufacture of slag-concrete bricks.

The present period is marked by the immense rivalry of gas with coal as a power-fuel. Either in the form of gas used directly, or decomposed from oil within the engine, it has invaded spheres where the steam-engine had no rival a few years ago. A vessel has recently crossed the Atlantic with engines driven by oil fuel. Many have been built or are now building in England and on the Continent.

Three causes have been and are increasingly contributory to this result—the enhanced cost of high-class fuel, the employment of electricity for power-driving, and the enormous potentialities of the internal-combustion gas or oil engine. The cost of fuel of high heating "calorific"—power concentrated attention on the enormous reserves of inferior fuels, in the heaps of breeze and waste rubbish in the immediate vicinity of collieries, which were accumulated in more halcyon days.

The Transformation of Cheap Fuels into Electric Current for Use as Light and Power

Electric developments have rendered it possible to transmit power over considerable distances, so that very large units of power can be produced in a very economical manner from cheap, poor fuels, and the power thus produced be distributed over a large area to works, tramways, and other undertakings. And the cost to these will not be nearly so high as it was when they generated their power in a smaller station, using expensive coal.

In fact, it is cheaper to sell waste heat or power to a central undertaking, and purchase it back in the convenient form of electric current, than to maintain a private electrical power-house driven by a steam or gas engine. Not only is the capital outlay much less in the large central plant, but the expenses of attendance are less in proportion to the output; and, further, the existence of a large central power-house for a district, taking the waste heat from a number of firms, is more favourable to such a complete utilisation of that waste than can ever be secured by a private firm.

Much of the power-gas which is specially manufactured for use in engines is got from inferior fuel that was formerly wasted, accumulating in huge mounds around the mouths of the pits. The fuel, for instance, from which Mond gas is made is of this character. It is common bituminous slack, obtainable for 3s. to 4s. per ton at the pit's mouth. Gas can be produced from it at the factory for ½d. per unit. But, besides this, the sulphate of ammonia obtained as a by-product in the process is worth nearly as much as the cost of the fuel. From 120,000 to 150,000 cubic feet of gas are got from a ton of fuel. There is already nearly 100,000 horse-power of gas-engines which derive their power from "Mond" gas, and a huge aggregate of this gas is further employed for heating in furnaces of all kinds, in engineers' works, glass-works, chemical works, earthenware and similar industries.

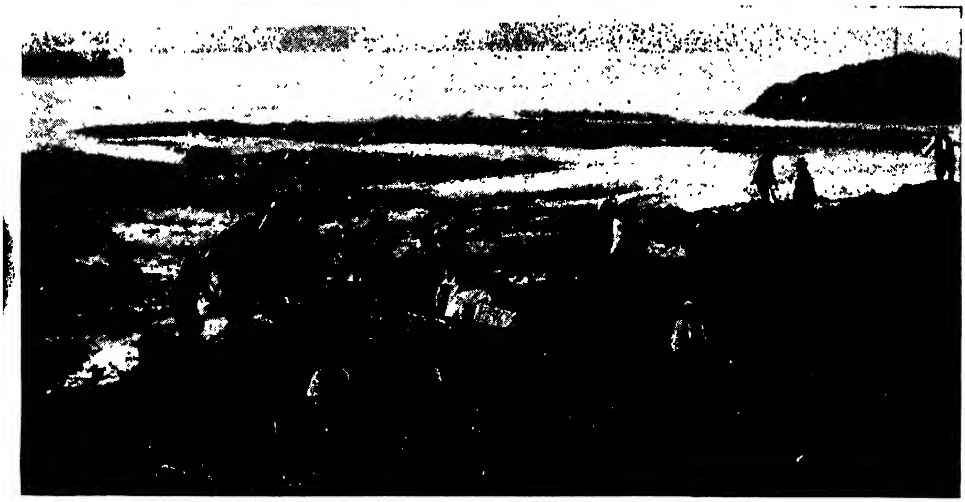
Will the Time Come when Nations can be Supplied with Power from one Centre?

Over a million horse-power of big waste gas-engines are now in use in the world. Of these, Germany employs 46·5 per cent., and Great Britain only 2·4 per cent. America comes next to Germany, with 32·5 per cent. France, Belgium, and other countries show little better than England.

In some districts in Germany surplus portions of the waste gases from furnace coke-ovens are sold to the towns for illuminating purposes. In Westphalia alone, it was estimated a year ago that gas to the value of £2,000,000 yearly was being lost. Now a good many towns in this and other districts are taking this waste gas for lighting, and are closing their own gas-works. In one case the supply contracted for by the municipality had to be brought through thirty miles of pipes—a long distance for gas. The collieries in connection with Krupp's works at Essen are supplying many towns with waste gases.

The movement now in progress is not going to end with the supply of actual gas. The other supply, that of electricity, will go hand in hand with it. In time the great coal and iron districts of Westphalia and

SEA WASTE FOR THE HARVEST OF THE LAND



Along many parts of the coast, particularly on the Atlantic side, seaweed—the flotsam and jetsam of the waters—is collected and carried away, as is here shown, to improve the local soil, or to undergo processes by which its chemical constituents are extracted.

Silesia will supply both gas and electricity to the greater part of the German Empire. Waste furnace gases and coke-oven gases, and small and inferior coal, at present unmarketable, will be the materials by which the present inefficient and costly supplies will be driven out and revolutionised.

The North-East Coast is the home of a gigantic power-scheme, being dotted with power-stations belonging to the Newcastle-upon-Tyne Electric Supply Company, and other co-partner companies. Beginning work in 1889, it now covers an area of fourteen hundred square miles, which extends from Blyth in the north, to Guisborough in the south; and from the coast westwards to Consett and Bankfoot.

One of the most striking facts in connection with many gas-producer plants is not only the gain of two, or two and a half, times over steam-power plants, but in the by-product recovery-plant attached thereto. It is literally true that in such cases firms get their gas for nothing, because the by-products pay the piper.

Gas, though it sounds paradoxical to say so, is both a primary and a by-product. There are two kinds of coke—that made for use in blast-furnaces, and that from which illuminating gas has been made. In the first the coke is the primary product, and gas is the waste; in the second, the gas is the primary product, and the coke is the waste. The two cokes are vastly different in composition: the first is hard, lustrous, and is nearly pure carbon; the second is soft, dull, and impure.

Where we Waste Yearly Three Million Pounds' Worth of Raw Material

Formerly there were no other by-products from the hard coke except the gases. Now most ovens are constructed to recover by-products similar to those which are obtained from towns' gas-retorts. These are chiefly tar and ammonia, from which the fertiliser sulphate of ammonia is obtained. The tar is distilled, and from it are produced naphtha, benzole, light oils, creosote oils, colour oils, aniline dyes, and pitch. It has been estimated by Mr. P. J. Mallmann that if all the ovens in the United Kingdom making furnace coke were to be operated so as to save all the by-products, £3,000,000 would be saved annually. The estimate is based on an annual consumption of 50,000,000 tons of coal in coke-making for furnace use.

Since the metropolis was startled by the pioneer station installed at Shoreditch, where the refuse of the borough was utilised to light the streets, many towns have treated their refuse as a valuable by-product. It is all treated in destructor furnaces, built generally with the brickwork regenerators of the steel furnaces. Also, from the burning of the refuse itself some by-products result, although the primary product is hot gases, which are consumed in boilers to raise steam to drive engines, that in turn generate electricity from dynamos. Actually it costs less to burn the refuse thus and employ the products than it does to tip the rubbish in heaps on valuable land. For every day it accumulates at the rate of from fifteen to twenty hundredweight for each one thousand of the population.

The Noisome Refuse of Cities Used to Light Them and Drive Tramcars

Yet the refuse is of very low value as fuel, being only from one-fifth to one-fifteenth that of coal, so low, in fact, that it can only be burnt in furnaces specially constructed for the purpose. Yet steam is produced at a pressure of 200 pounds per square inch from this waste rubbish.

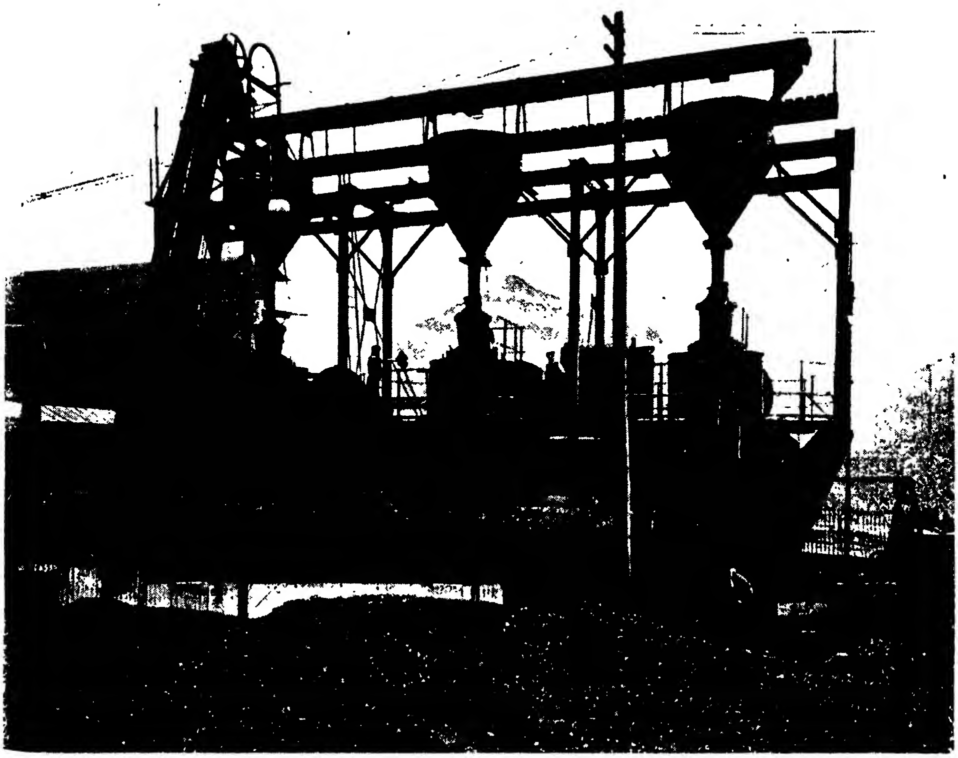
The furnaces variously differ, but in general they comprise separate combustion cells, the employment of forced draught, and the use of hot air treated in regenerators. Towns are lit and tramcars driven by the burning of the evil-smelling, disease-laden contents of the dustbins and rubbish heaps. Truly a splendid utilisation of undesirable waste!

The waste in fuel which is imperfectly burned has been estimated at one-third. That is, of 150,000,000 tons of coal consumed, 50,000,000 tons are wasted. The loss in the carbon visible in the smoke is but a small fraction of this amount, being only about one-half of one per cent. The far greater loss is due to unconsumed gases, which vary from 10 to 33 per cent. of the total heat. Sulphurous acid gas is one of the most important of these.

The Wealth that Escapes Visibly and Invisibly up our Chimneys

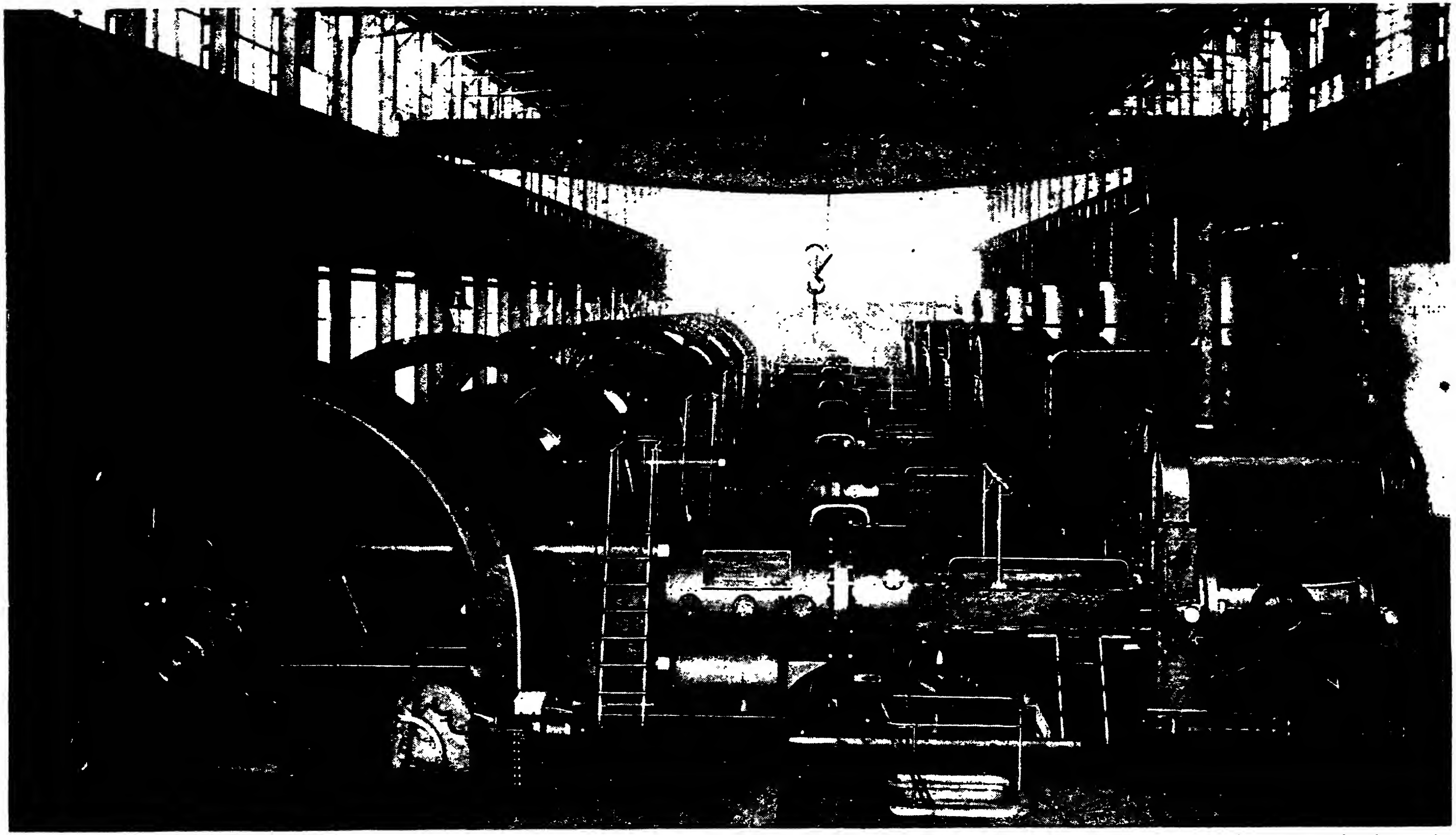
It is stated by Mr. T. B. C. Kershaw that ten thousand tons of sulphurous acid are deposited daily over the country from this source, or three and a half million tons per annum. One thousand tons fall daily on the metropolis. The smoke problem therefore assumes gigantic proportions, because it is one aspect only of the much wider question of imperfect combustion of coal, which can only be met by improvements in furnaces and in methods of stoking. There is scope here for a campaign against waste that would be gigantic in its benefits.

VAST POWER FROM OBSTRUCTIVE REFUSE



The upper photograph shows a Mond gas plant, used at a colliery near Stoke, for making gas for driving gas-engines. All the power needed at the colliery is produced from such refuse as coke-breeze. Valuable sulphate of ammonia is also extracted in the gas-making process. The lower picture shows a 6000 horse-power Mond gas plant that uses up each week 60 tons of the slack seen in the foreground.

SEVEN 600 HORSE-POWER GAS-ENGINES WORKED BY WASTE GASES FROM BLAST FURNACES



In Germany waste gases from blast furnaces are used largely for running gas-engines. That the device is adopted to some extent in this country is shown by the above installation of engines at the Cargo Fleet ironworks at Middlesbrough.

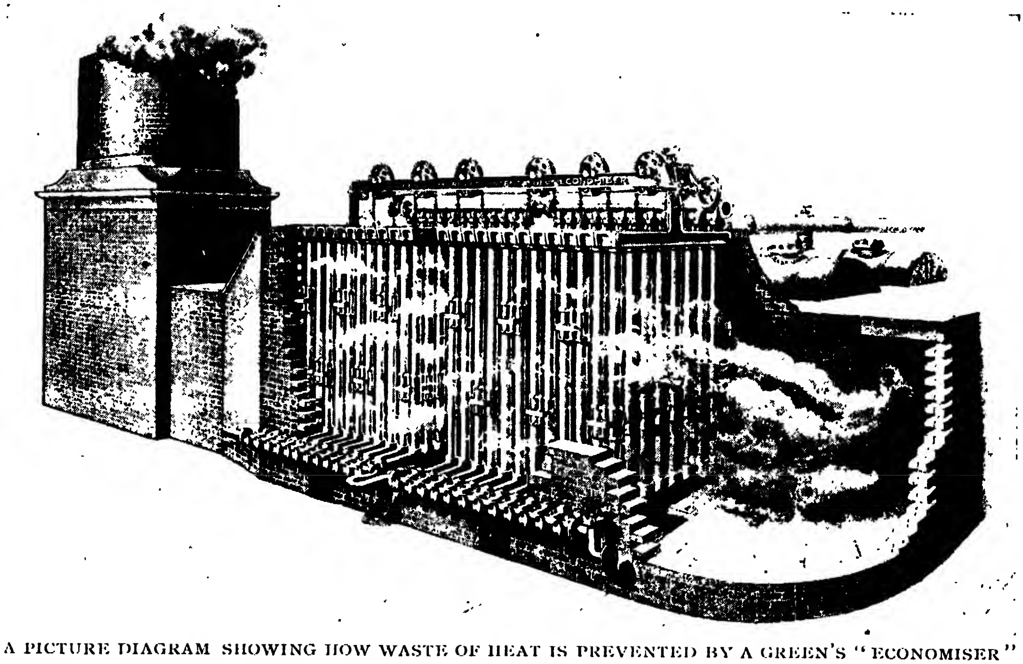
The task of the engineer is to harness and direct the forces of Nature into channels for the service of mankind. He is an Idealist as well as a Utilitarian. He abhors waste, yet he is ever faced with the fact of immense wastes of energy in every engine and machine he builds. The greatest forces in the world—the waterfalls, the tides, the wind, the sun himself, the very springs of potential energy—are lavished in vain in the sphere of human industry, while the muscles of poor humanity are put to incessant overstrain, and the soul of the toiler is brutalised by the ceaseless drudgery of his tasks. The engineer has done much to alter this, but almost always by the help of one agent—the sun's energy, which was stored up millions of years ago in coal.

In recent times the harnessing of the power of falling water has become so familiar that it arouses little wonder. The old water-wheels, clumsy and inefficient, have given place to the smaller but more powerful turbines. These are adaptable for falls of from four to a thousand feet. At Niagara, at the Victoria Falls, in California, Switzerland, South Germany, France, Scandinavia, Italy, the volume of water-power increases and the steam-engine disappears. Yet but for the fact that the electric dynamo has been developed along with the turbine, changing the rotation of the latter into electricity, not one thousandth part of the water-power that is now utilised could have been developed.

In the early days such power was transmitted from the turbines for short distances only. Now electricity is carried hundreds of miles in some installations, driving trams and machinery and mines, and illuminating teeming cities far removed from the roar of the cataracts. Every year the amount of water-power laid under contribution increases by leaps and bounds. Yet what is taken is ridiculously small by comparison with what remains unutilised.

Practically all the potential power stored in the wind is wasted daily. Only a very infinitesimal proportion is utilised. Yet lavish Nature makes no charge for wind. A windmill is one of the simplest pieces of mechanism made by engineers. It is so simple in construction that breakdowns are rare. There is no trouble with boilers, or furnaces, or fuel storage. And if it be objected that wind-power is intermittent, so, too, is much of the work for which engines are used. A windmill can be relied on to run, say, eight hours out of the twenty-four, and electric storage cells will provide supplies for the other hours.

The principal work done by windmills is pumping, chaff-cutting, grinding, and driving small machinery for farm work.

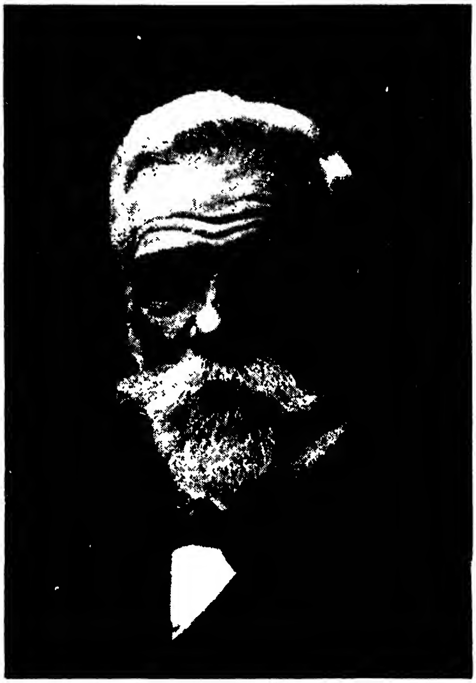


A PICTURE DIAGRAM SHOWING HOW WASTE OF HEAT IS PREVENTED BY A GREEN'S "ECONOMISER"

In many cases country houses are lit by electricity through the help of storage cells. A modern windmill, not the antiquated structure beloved of artists, is an excellently made piece of mechanism, with ball bearings, and having self-acting mechanism by means of which the vanes or sails themselves turn to meet the wind as its direction changes. Assuming an average velocity of wind at fifteen miles an hour, a mill with sails twenty-two feet in diameter at thirty-six revolutions per minute will give out one horse-power. Many mills are larger than this, ranging up to forty feet in diameter. At some not very distant day, when the coal problem becomes acute, the long-neglected windmills, dating from the twelfth century, dispossessed of their ancient favour by the fussy steam-engines, will come into their own again.

In all industrial lands inventors have longed to utilise the vast amount of power lavishly poured out and wasted daily by the beneficent heat of the sun shining on the waste places of the earth. Many attempts have been made to harness these rays for useful work; and some day, when the coal famine is upon our descendants, the idea of sun-power may become matured, and the problem of smoke consumption will then cease to worry. Sun-power motors, to be commercially successful, must, for the present at least, cost less to maintain than those which require coal or other fuel to drive them. They can only, therefore, be utilised in countries where coal is costly, and of course, too, under cloudless skies. These two conditions exist in tropical lands, but not in Britain, nor in any of the Northern European countries.

Immense sources of wealth lie in the by-products and wastes of many industries outside the power agencies we have been considering. Many people wonder what becomes of all the various scrap metals. A Report issued in the United States for 1910 will give some idea of the extent of the scrap trade. The amount of metals recovered from waste during that year as scrap sweepings, dross, etc., amounted to 45,525,500 dollars in value. No fewer than 51,000 tons of copper were recovered from alloys other than brass; 62,000 tons from brass; 55,323 tons of lead from alloys; 43,932 tons of zinc; 12,903 tons of tin; and 2779 tons of antimony.

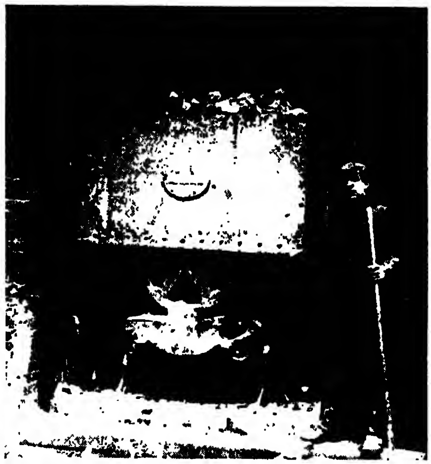

MR. ERNEST SOLVAY

The chemist is a magician more potent than any who charmed our boyhood in the "Arabian Nights." Locked up in the coals are hundreds of lovely dyes which he extracts by distillation and solution. These are all by-products, and until Perkin, in 1856, discovered their value, were absolute wastes. Previously only tar was recovered, a crude substance having such limited utilities that it was of slight value by comparison with its separate constituents, and was, in fact, often burnt to get rid of it. Actually this black and sticky tar is a compound of about two hundred different substances, occurring in larger or smaller quantities, and of less or greater value.

The marvellous story of the coal-tar dyes is one of the romances of industry. Fifty years ago they were unknown. Previously all the dyes used had been derived from the animal or vegetable kingdom. These were mostly unstable; some were procured with difficulty. But they had no rival until, in 1856, Mr. Perkin obtained the first aniline mauve dye for silk. This was followed by the discovery of aniline magenta. Until 1860 these were the only dies made from coal-tar, and magenta then fetched £30 per pound. Afterwards aniline blue was also obtained, and subsequent progress was rapid.

Now there are some hundreds of dyes derived from coal-tar, every one being a definite chemical substance, though known only to the trade and to the public under common names.

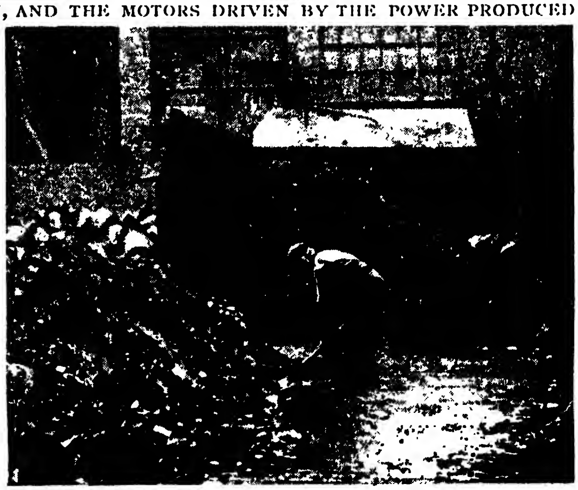
BRINGING POWER FROM A RUBBISH HEAP

HOUSE REFUSE BROUGHT TO A DUST DESTRUCTOR AND LOADED ON AN ELECTRICALLY DRIVEN BIN


THE FURNACE THAT BURNS THE RUBBISH, AND THE MOTORS DRIVEN BY THE POWER PRODUCED

THE HUGE SWITCHBOARD THAT CONTROLS THE ELECTRICITY PRODUCED BY RUBBISH

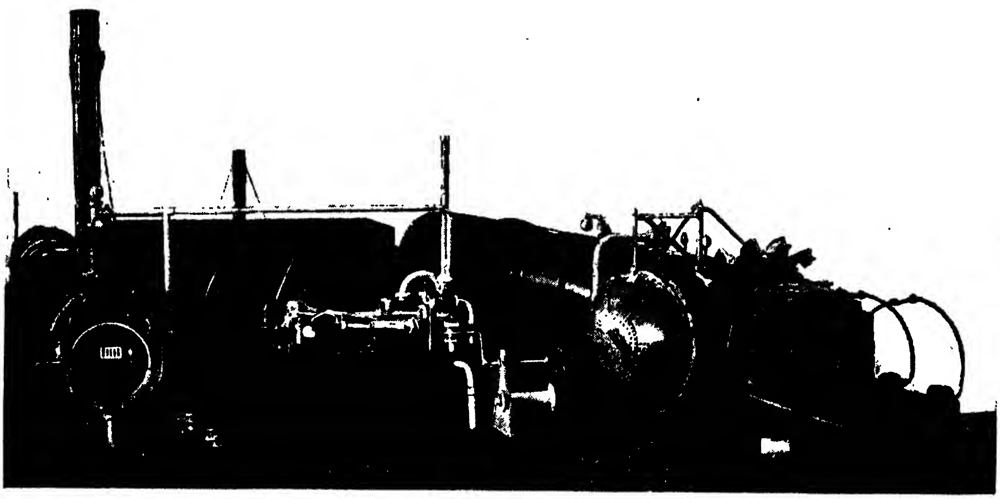


STORING THE ROUGH AND GRADED CLINKER FROM THE FURNACES FOR USE IN BUILDING AND ROADMAKING

Lord Beaconsfield rung the true note when he advised an audience to keep their eyes on chemicals. Chemicals, and what are they? Well, alkalies and acids, sulphates and chlorides, and chiefly carbonate of soda and sulphuric acid. Chemicals lie at the basis of cheap soda, cheap soap, bleaching-powder, dyes, oils, calico and woollen industries, pottery, gold extraction, baking-powders, washing-blue, paper-making, ordinary paints, photography, glass-making, explosives, enamels—and hundreds of industries. Some of these are primary products, many are by-products, once wastes and disagreeable things to be got rid of, but now of high value.

There are cases in which a more expensive and roundabout process is chosen, rather than a less costly one, by which to manufacture a primary product solely in order to be able to sell by-products. Thus, the Solvay ammonia process for the preparation of the carbonates of soda is much cheaper and simpler than the Le Blanc process. Yet the latter is often adopted in order to obtain bleaching-powder and chlorates as by-products, and, in a lesser degree, the sulphur in the residue. Hydrochloric acid gas was a by-product in the Le Blanc process which, until a way was found to condense it in water, was a very grave public nuisance. By means of Gossage's condensing towers this waste gas is now practically all condensed into wealth.

Undoubtedly the most valuable single product, after iron, is soda. It has taken the place of the potash once extracted from wood ashes and seaweed. Le Blanc (1742–1806), competing for a prize of £100 offered by the French Academy of Sciences for a method of turning salt, which is plentiful, into soda, invented the process known by his name. He treated salt with sulphuric acid, producing sulphate of soda —"salt cake"—and hydrochloric acid gas. To the salt-cake he added charcoal and chalk, and by slowly heating the mass produced carbonate of soda, leaving a heavy, grey, muddy sediment, "alkali waste," in which later investigators have found a source of great wealth. No other process was employed until 1872, when Ernest Solvay invented the one known by his name, in which less than half the fuel required for the other is used, and no solid residue is left. In 1800 the price of soda crystals manufactured from the ashes of seaweed was £60 a ton. The present quotation is £3 2s. 6d.



THE PLANT USED FOR CREOSOTING RAILWAY SLEEPERS WITH THE WASTE PRODUCT THAT IS OBTAINED FROM COAL TAR

The waste products of the Le Blanc process were the hydrochloric acid gas evolved by the contact of the sulphuric acid with the salt, and the grey, muddy sediment. The first was nothing but a nuisance until Mr. Gossage invented a method of its recovery by its condensation and absorption in a descending stream of water in a tower. This acid is composed of hydrogen and chlorine. Now, chlorine had been known since the days of Watt as a powerful bleaching agent, accomplishing in a few hours what had required exposure to

RESCUING POWER FROM WASTED WIND

In recent years wind-power has been sought afresh, particularly for pumping water. Here we have two examples of modern windmills, adaptable and graceful, quite unlike the lumbering stability of old mills.

The photographs on these pages are by courtesy of Messrs. E. Green & Son, Ltd., Wakefield; Cowans, Sheldon & Co., Ltd., Carlisle; R. Warner & Co., Ltd., Walton-on-the-Naze; Richardsons, Westgarth & Co., Ltd., Hartlepool; The Power Gas Corporation, Ltd., Stockton-on-Tees; and Messrs. Cammel-Laird

sunlight for a whole summer to effect. Chlorine was utilised in the form of chloride of lime, or bleaching-powder. But the manufacture involved the use of manganese, all of which was wasted, along with two-thirds of the chlorine. Later, the manganese was replaced by a method in which hydrochloric acid gas was passed over heated copper salts, with the evolution and recovery of all the chlorine. This left only the foul-smelling grey residue to be dealt with. The objectionable element in this was sulphur. Finally, by the Chance-Claus system, the sulphur is recovered in kilns by means of air and the waste gases from lime-kilns, so that now the cycle is complete without waste.

When the Solvay soda-ammonia process was introduced, the Le Blanc industry would have been killed but that the recovery of the wastes saved it from destruction. Bleaching-powder of 35 per cent. strength is now quoted at £4 5s. per ton, and recovered sulphur at £5 a ton, while soda is only £3 2s. 6d. per ton. Thus the by-products fetch more than the original or primary product!

The Great Part Played in Modern Industry by Sulphur

One cannot easily get away from the alkalies and their by-products. Take sulphur, and sulphuric acid, or "vitriol." Sulphur is an element the demand for which still increases. It is used in the manufacture of gunpowder, of vulcanised rubber, in bleaching silk and woollen goods, in washing-blue, in paper-making, etc. It is stated that 200,000 tons of sulphur are used annually in the wood-pulp paper industry alone. Without an abundant supply of sulphur the manufacture of alkali by the Le Blanc process is impossible. But outside of this it has a hundred applications, many of which lie in the extraction of wealth from waste. Take bones, for example, in which an immense trade is done. These are converted into valuable manures by crushing them and subjecting them to the action of sulphuric acid, yielding phosphoric acid and superphosphates. The United Alkali Company alone turn out 100,000 tons of this material annually.

Now, sulphur is a by-product in the Le Blanc process. But it is a primary product in the roasting of pyrites, the chief supply of which comes from Spain. Arsenic, copper, iron, and minute quantities of silver and gold are also by-products, but were for many years ugly heaps of waste. After the sulphur was expelled from the pyrites by roasting, the residue was waste. The quantity of copper present was very small. But at length the cinders were ground to powder, mixed with salt, and roasted, yielding copper chloride, which was rendered soluble in water along with the silver and gold, which were afterwards recovered, leaving a pure iron oxide that is melted in the blast-furnaces. The result now is that the quantity of copper in the pyrites, and not the sulphur, regulates the price; and, as copper is high, pyrites have risen in sympathy.

Soda and Potash as Up-to-date Gatherers of Gold

Sulphuric acid is the most important chemical employed in industries. It is made directly from sulphur, or from iron pyrites. Yet twice as much sulphuric acid is wasted by the consumption of coal in the kingdom as is used for manufacturing purposes. Each ton gives off about 68 pounds of sulphuric acid, to the great damage of public buildings and the contamination of the atmosphere.

Without soda, or its first cousin, potash, the gold industry in the Transvaal could not have attained its present vast proportions. Gold is extracted from its ores, after crushing the rock, by taking advantage of its affinity for cyanide of soda, or potassium. Cyanide is a compound of soda with prussic acid. Some thousands of tons of this material are produced at Runcorn by the United Alkali Company, Ltd. Chlorine, a by-product, suffocating as a gas, is yet one of the most valuable disinfectants known. Dissolved in water it is used for many purposes, for which neither carbolic acid nor mercuric chloride would be safe or suitable.

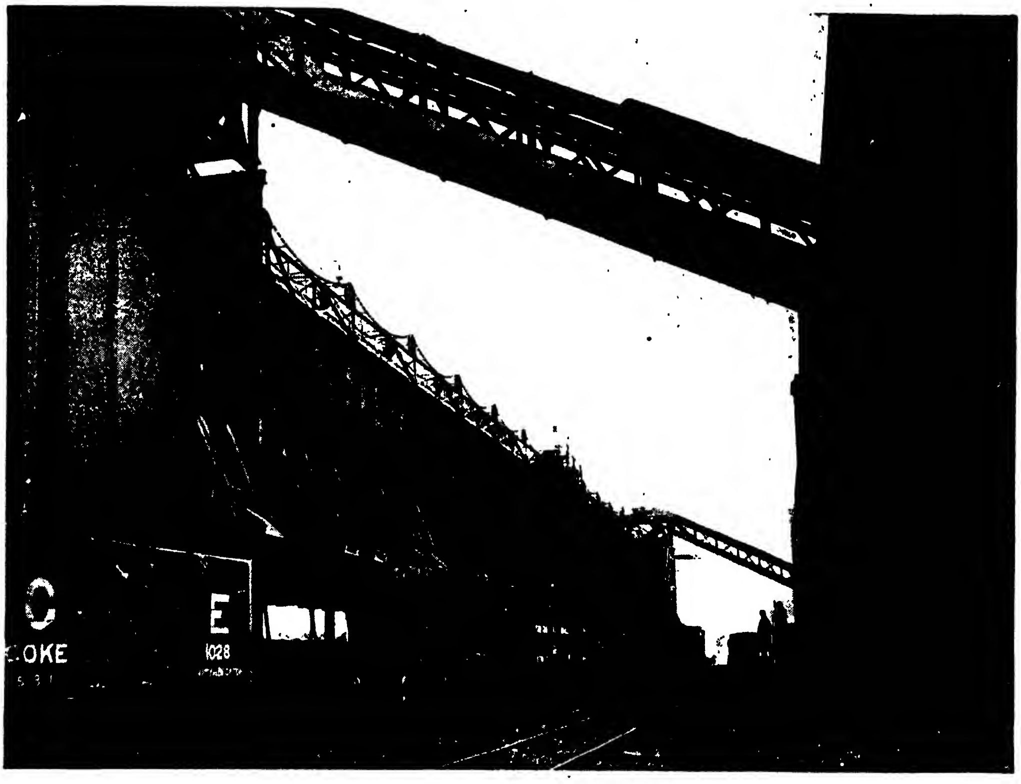
The Plush-Making Romance that Grew into Manningham Mills

The story of the invention of the plush loom by the late Lord Masham (Mr. Lister) is one of the utilisation of waste absolutely. The stuff was waste silk, "chassum," from India, thrown out in the manufacture, and consisting of pierced cocoons, dead worms, mulberry leaves, and dirt. Mr. Lister bought a pile of it for a halfpenny a pound, and spent twenty years in perfecting a process and a machine by which this uninviting rubbish was dressed and woven into "pile cloths" or "plush goods," as silk velvets, imitation sealskins, velvet ribbons, etc. He sunk many thousands of pounds in these efforts, but at last the corner was turned, and before long

5000 persons were employed in the new industry at the Manningham mills. Some years later the mills were converted into a limited liability company, capitalised at nearly £2,000,000.

Enormous wastes occur in the great manufacturing towns in the form of trade effluents, to check which the Rivers' Pollution Act was passed. The streams in Yorkshire and Lancashire are little better than open sewers of blue-black hues, embroidered with patterns in oils and grease, the despair of municipalities and and dyeing, paper-making, each disgorge wastes of special character, forming an aggregate total which, when poured into the streams, renders them unsuitable even for use by the manufacturers on their banks.

The difficulties lie in the very varied character of the wastes, and in the cost of the plants required for their recovery. As, too, in towns' sewage, one great obstacle lies in the immense amount of liquid present in which substances are held in solution. Solids would not offer a fraction of the



HOW COKE IS LOADED INTO TRUCKS AT A GASWORKS

The coke is placed on an endless chain in the retort-house, and is thus carried into the hoppers seen in this picture, and loaded into railway trucks.

sanitary authorities. A problem similar in character, but of universal interest, is that of the disposal of towns' sewage. In each the effluents are rich in elements which have industrial value, but methods of separation and questions of cost often set up grave obstacles to their utilisation.

With regard to trade effluents, the worsted and woollen trades are the worst offenders in poisoning and discolouring the streams. Brewery and distillery wastes are, however, very large. Tanning supplies a serious quota; calico bleaching, printing, difficulties in their utilisation. In towns' sewage the older method of sewage farming is being superseded by the bacterial system, with septic tanks and filter beds. The work of purification is divided between the aerobic and the anaerobic bacteria. The latter in the septic tanks disintegrate and liquefy solid particles, and ammonia is formed. Afterwards, by the aerobic bacteria in the filters, ammonia, carbonic acid, and nitrates are produced, leaving a clear, innocuous effluent, while the solid particles have a varying value as manure.

THE RAILWAY STRIDE ACROSS THE DEEPEST GORGE OUTSIDE OF THE ROCKY MOUNTAINS

This bridge over Pembina River on the Grand Trunk route is 300 yards long and 213 feet high—the highest on any of the prairie sections of the continent. The inclined planes on either side of the stream were used to pass railway-making material across the river while the bridge was being constructed.

The illustrations to these pages are from "The Making of a Great Canadian Railway," by Mr. F. A. Talbot, published by Messrs. Seeley, Service & Co., Ltd., the Canadian Grand Trunk Railway Company, the Chilian Transandine Railway Company, the British South Africa Company, and Tanganyika Concessions.

OCEAN TO OCEAN RAILWAYS

The Conquest of the Earth by the Straight and Level Steel Track

ROMANCE AND ADVENTURE IN INDUSTRY

THE Russians had a sure instinct when, on rounding Lake Baikal, in Central Asia, with their Trans-Siberian line, they put on the western end of the central tunnel a conspicuous inscription, "To the Great Ocean," and on the eastern end, "To the Atlantic Ocean." No railway can stir the imagination like one that bestrides a continent and links oceans far apart. In only six cases have such railways been made—the first, forty-two years ago, the last, in 1910. In no other work of human hands on a gigantic scale have the spirits of romance and adventure been so closely allied with industry, or, indeed, with any enterprise except man's first voyaging round the world.

Only in Asia, Africa, North America, and South America can there be a great, through, direct inter-oceanic railway of the kind that appeals to the imagination. Such a line cannot be laid in Europe, which, geographically, is only patched on to Asia; and, besides, is filled with fragmentary railway systems, adapted to the needs of a number of neighbouring, but not very neighbourly, countries. The railways of these countries are pieced together more or less by accident, for they were conceived primarily to serve the purposes of each separate State.

A journey like that from Calais to Brindisi, or that from Ostend to Constantinople, though passing from sea to sea, does not give the impression of unity of aim in carrying through a continental enterprise. The mere interposition of carefully safeguarded frontier lines would suffice to destroy the conception of a European common road, even if there were stronger evidences of co-operation than are furnished by an international carriage company, buying its way across country after country by supplemental fares, which is almost the only sign of railway co-ordination in Europe. No; Europe will never have a truly trans-continental railway until it has a federation of States, with unity at the heart of its financial and industrial policies. The past of all its railways is against this broader conception; and, besides, there is but little room left for any great new scheme. Europe's railways must remain a magnificent agglomeration of local enterprises.

It is the same with the compact island-continent of Australia. Settled in separate patches, each with its own Government and interests, and network of communications, and with no Beyond to the east or the west, except one or two adjacent and similar Colonies, what reason can be found for a great through line, swiftly sweeping, say, from Perth to Brisbane? A series of local railways, judiciously joined, serve the purposes of the Colonies and the continent very well, and the ocean remains the natural through-route for Australia.

Africa is the one continent that can still have a trans-continental railway—it will have several, presently—but as yet is only in the stage of creeping forwards towards that desirable consummation. The Cape to Cairo railway-cum-waterway has long passed beyond the stage of hopeful forecast. It is being accomplished piecemeal, without the aid of any such inspiring imagination as gave it a start in the mind of Cecil Rhodes.

What is now clear is that as this line progresses into equatorial regions it will be fed by branch lines from the east and the west, to a degree far beyond what was originally counted on, and when it passes from the somewhat supine fringe-lands of British influence into the regions actively occupied by the Germans and Belgians, it will be pushed on faster than it has grown during any stage of its advance from the south. From it will spring branch routes

through the Congo State to the West Coast, and also, probably, through Central Africa to the Niger, and even past Lake Chad to the desert regions and Algeria, so that Africa will be doubly crossed, both from north to south and from east to west.

The enormous distance to be traversed by the Cape to Cairo Railway, even after the northern and southern sections—established irrespective of the "through" idea—are taken into account, makes the enterprise appear colossal, and this view is emphasised when we realise the special character of the difficulties that await the railway maker in the equatorial regions, and the meagre economic needs of the people of the lands through which the line must pass. There cannot be much trade with people who have not a pocket in which to put anything.

The Egyptian line is fully worked to Khartoum. The Cape line proper may be said to extend from Capetown to Vryburg, a distance of 804 miles. This is the Cape Government's section. The extension to Mafeking and Bulawayo carries the passenger 1362 miles away from Cape Town, and further additions have reached Broken Hill, a distance of 2017 miles from the southern sea.

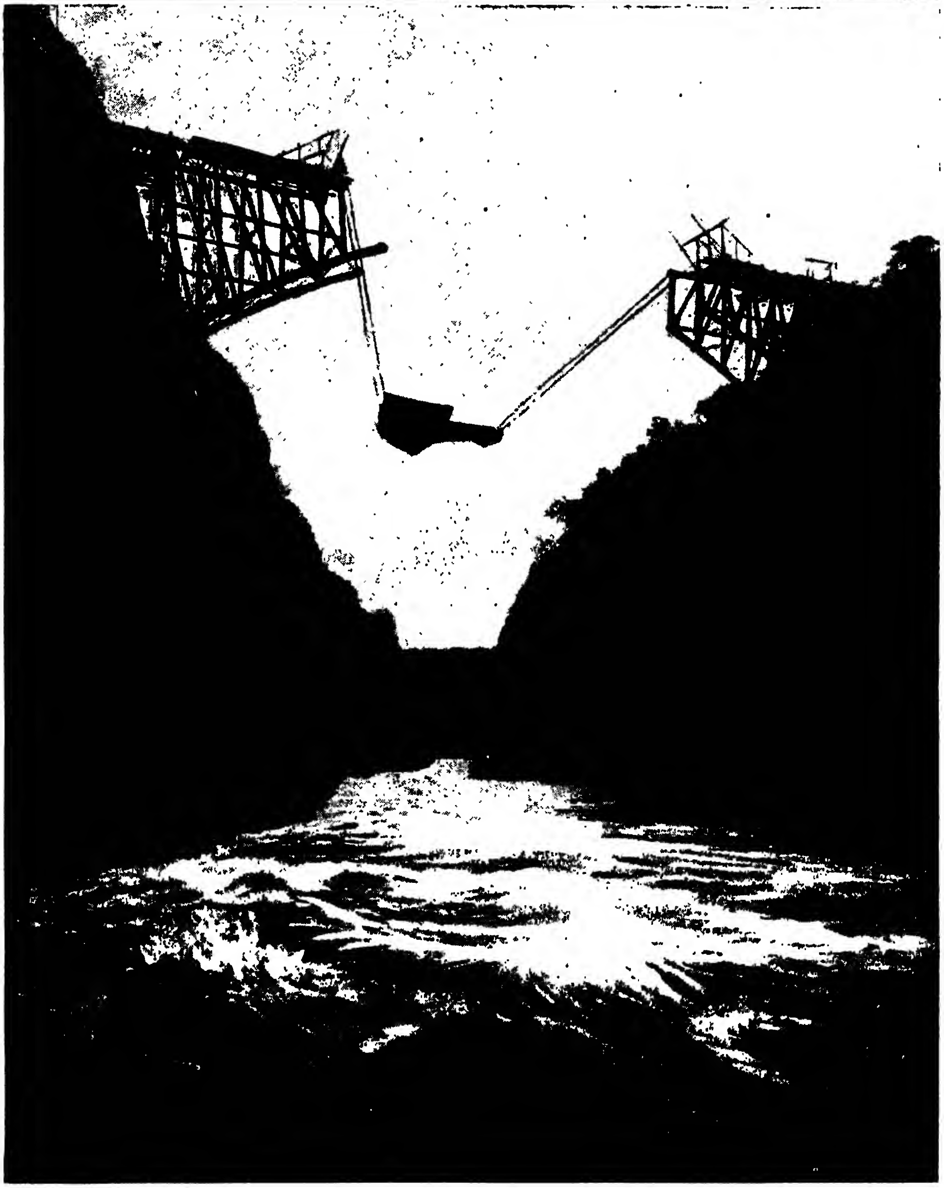
The route northward is following slowly the clearing cut for the Cape to Tanganyika telegraph line. Eventually the progress made must depend largely on the goodwill of the German and Congo State Governments, for the route will pass through their territories before it can link together the three great waterways—Lake Tanganyika, Lake Albert Nyanza, and the sudd-impeded equatorial Nile. That these regions, where the wealthy traveller now only makes his way with difficulty, will presently be crossed on the steam-traversed steel track cannot be doubted for a moment by anyone who knows the rapidity of modern progress, but for some time after its completion an ocean to ocean railway in Africa must remain a rather expensive experiment in pioneering, used for curiosity almost as much as for trade.

Though the ocean to ocean railways of other continents are works of stupendous magnitude, nothing that has been done, or that remains to be done, can equal the task of fighting distance and climate through the dry uplands, the dense forests, and the widespread swamps of Africa. Especially does the water-logged condition of the equatorial region present difficulties. Though between Capetown and Cairo there are stretches of waterway, amounting in the aggregate to 1650 miles, that render railway traffic unnecessary when the waters have been properly cleared of weeds, this waterway might all be given up with advantage if the few hundreds of miles of undrainable water could be got rid of from the spongy waist of the continent.

In May, 1910, the first ocean to ocean railway was completed between the eastern and western coasts of South America. The tunnel through the crest of the Andes, at a height

LAYING THE RAILS OF THE TRANS-SIBERIAN RAILWAY

BRIDGING A GORGE OF THE ZAMBESI



One of the triumphs of engineering in building the projected Cape to Cairo railway was the construction of the bridge across the gorge below the Victoria Falls. This bridge is 420 feet above the water.

of 12,600 feet, was brought into use, and the direct connection made between Buenos Aires, on the flat Atlantic coast of Argentina, and Valparaiso, in Chile, at the Pacific foot of the mighty Andes. The railways of Chile, Peru, and Bolivia, which climb the sudden and stupendous steepness of the Andean range, are among the most sensational in the world, and the one which has more than a local character is this link between the prosperous east and prosperous west of the Latin American continent.

Starting from the level of the sea at the great million-peopled capital of the Argentine Republic, the line crosses the level pampas of Argentina to the prosperous city of Mendoza, whence its climb of the continental backbone begins, right up to the supporting ridges of the mighty Aconcagua, where, at a height of 12,600 feet, it tunnels the crest of the ridge at the pass of Uspallata, and descends swiftly to Juncal and Los Andes, and so down the Andean rampart to Valparaiso—by fifty per cent.—the highest trans-continental railway in the world.

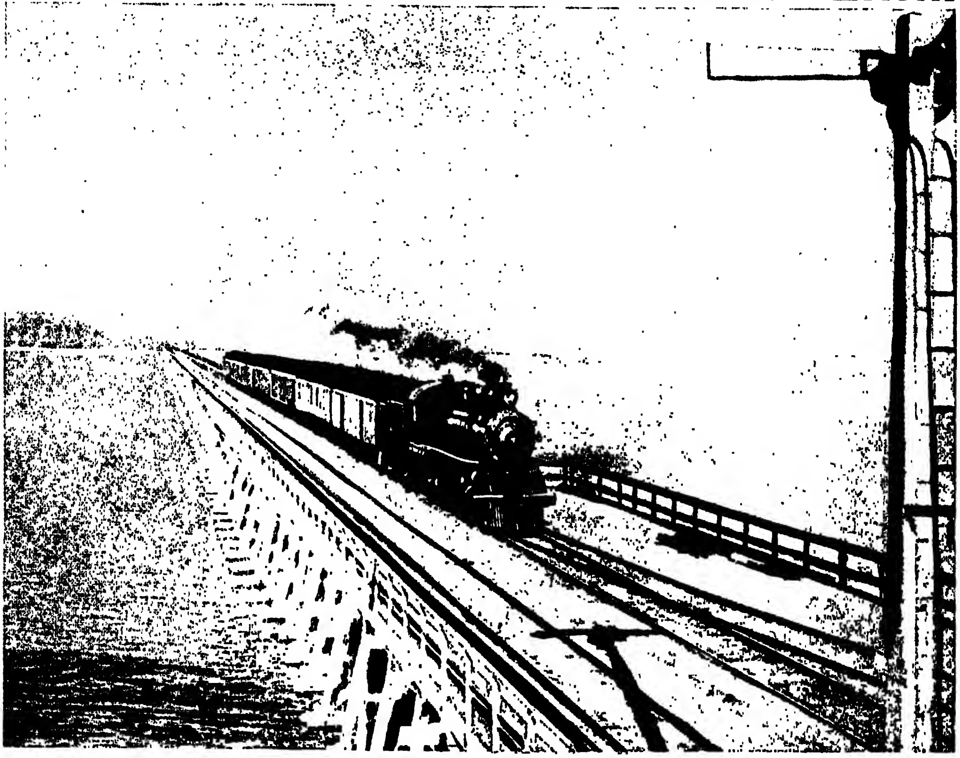
While Europe and Australia cannot have trans-continental railways on a grand scale, and Africa is only tentatively feeling her way, half in hope and half in fear, towards a great scheme, international in scope and spirit, South America, the continent of greatest hope, about which the world's northerly population knows least, has won her spurs as a continental railway-maker, following in that respect Asia and the North American continent. If we refer next to the great Trans-Siberian railway, it is that we may leave for fuller notice the magnificent steel thoroughfares of the Western world.

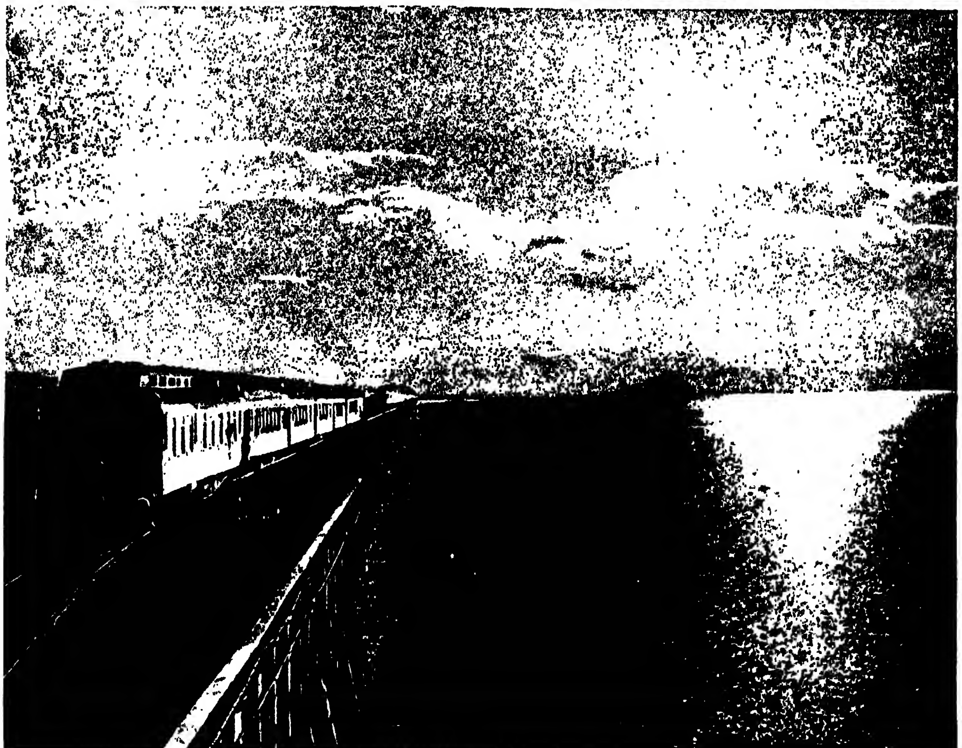
The building of the Siberian railway was one of the events that has influenced profoundly the immediate future of the world. It was the last of the calls that woke up the slumbering East. As lately as March, 1891, the Russian Emperor ordered by rescript that the railway should be made; the first sod was cut in 1892 by the present Tsar, who was then visiting Vladivostok, and in a little more than eight years Russian military trains went down to Port Arthur, six thousand miles away, from St. Petersburg.

From the beginning to the end of that huge railway track strange things have happened. It has created the agriculture of

NATIVES CARRYING THE RAILS OF THE CAPE TO CAIRO RAILWAY

A TRAIN CROSSING A GREAT LAKE





The first American transcontinental line has been shortened by "cut offs" amounting to more than a hundred miles, including this trestle bridge across Salt Lake

CLEARING THE FACE OF THE TUNNEL THAT NOW LINKS ARGENTINA WITH CHILE

SPRING AND SUMMER ON THE ANDES LINE

The railway from Buenos Ayres to Valparaiso rises to a height of over 12,000 feet, and then tunnels through the crest of the Andes. The upper pictures show the reopening of the line after the winter snows; and the lower picture its appearance when under construction in summer.

Siberia—a country that is taking a high place among the lands that feed the city-bred people of England. It fed up Russia's military ambition and desire for a warm-water Pacific port, until that ambition perished with a crash in a struggle that showed how very wideawake the Far East had become. It was the railway that made the great Russo-Jap war possible; nay, according to the Japs, inevitable. And now that its military phases have proved tragic, with heavy rapping of the knuckles that held the field-marshals' bâtons, the railway is doing real business.

It has brought Shanghai within fifteen days of London; it carries the European mails of the now friendly Japs. With only one change of carriage you may travel from Ostend on the North Sea to Vladivostok on the Pacific Ocean; and you may do this in a state of luxury rarely met with in any other part of the railway world. Twenty years ago the worst penalties of a crossing of Siberia were the insanitation, dirt, and verminous surroundings that could not be escaped. Now the Trans-Siberian gives the traveller all the resources of a well-ordered club, up to the latest books read by electric light, a comfortable bathroom, and tempting cuisine, and this is supplemented by the chance of attending church in the train. On March 29 of this year, twenty-one years will have passed since the Russian Emperor said, "Make a railway to the Pacific Ocean," and it has not only been made, but largely re-made, with the result that the invalid traveller can loll at ease while he is hauled through an empire maintaining a new belt of population, and is guarded by a succession of sentinels within sight of each other from the Ural to the Pacific.

A wonderful line, no doubt, if we look at the labour that made it, and the results it has produced in a part of the world that was practically unknown; but not a favourable example of how a railway should be planned, or financed, or constructed, or worked. Rather, the truth is that, however considerable the financial and national success of the Trans-Siberian railway may have proved, the line illustrates all the worst weaknesses of inept engineering.

CLEARING THE FOREST AT THE PRINCE RUPERT END OF THE CANADIAN TRUNK RAILWAY

The track had already penetrated two hundred miles into Siberia, to the town of Tchelyabinsk, 1776 miles from St. Petersburg, when the order went forth that it must be continued to the other side of Asia. The first 2000 miles of this great journey was easy-going, but for the bridging of the

BRIDGE BUTTRESSES ON A PRAIRIE LINE

The Canadian prairie soil contains very little stone, and the shore ends of bridges have to be supported by deeply sunk buttresses. The illustration shows the preparations for the Clover Bar bridge.

rivers Obi, Irtish, and Yenisei. Lake Baikal, lying in a rugged mountain basin right athwart the path of the line, was for years a harassing barrier that was crossed by steamer, or on the ice, or, later, by a train ferry. Now, however, the southern end of the lake has been turned, by a railway détour from the straight course that has cost about six millions of money, and has involved the piercing of thirty-three tunnels, totalling about four and a half miles of length, with two hundred bridges and viaducts. This great work was forced into activity by the Russo-Jap war, as the original railway communication, broken by the lake, had failed even beyond the anticipation of engineers who knew how short-sightedly it had been carried out. At Kaidalovo, beyond Lake Baikal, the direct through route leaves Russian territory and passes for 890 miles—though still under Russian management—through Chinese Manchuria to Vladivostok; while the all-Russian route, bearing away north-eastward from Kaidalovo to Stretensk, reaches Khabarovsk by the navigation of the River Amur, and thence, over resumed rail, arrives at Vladivostok.

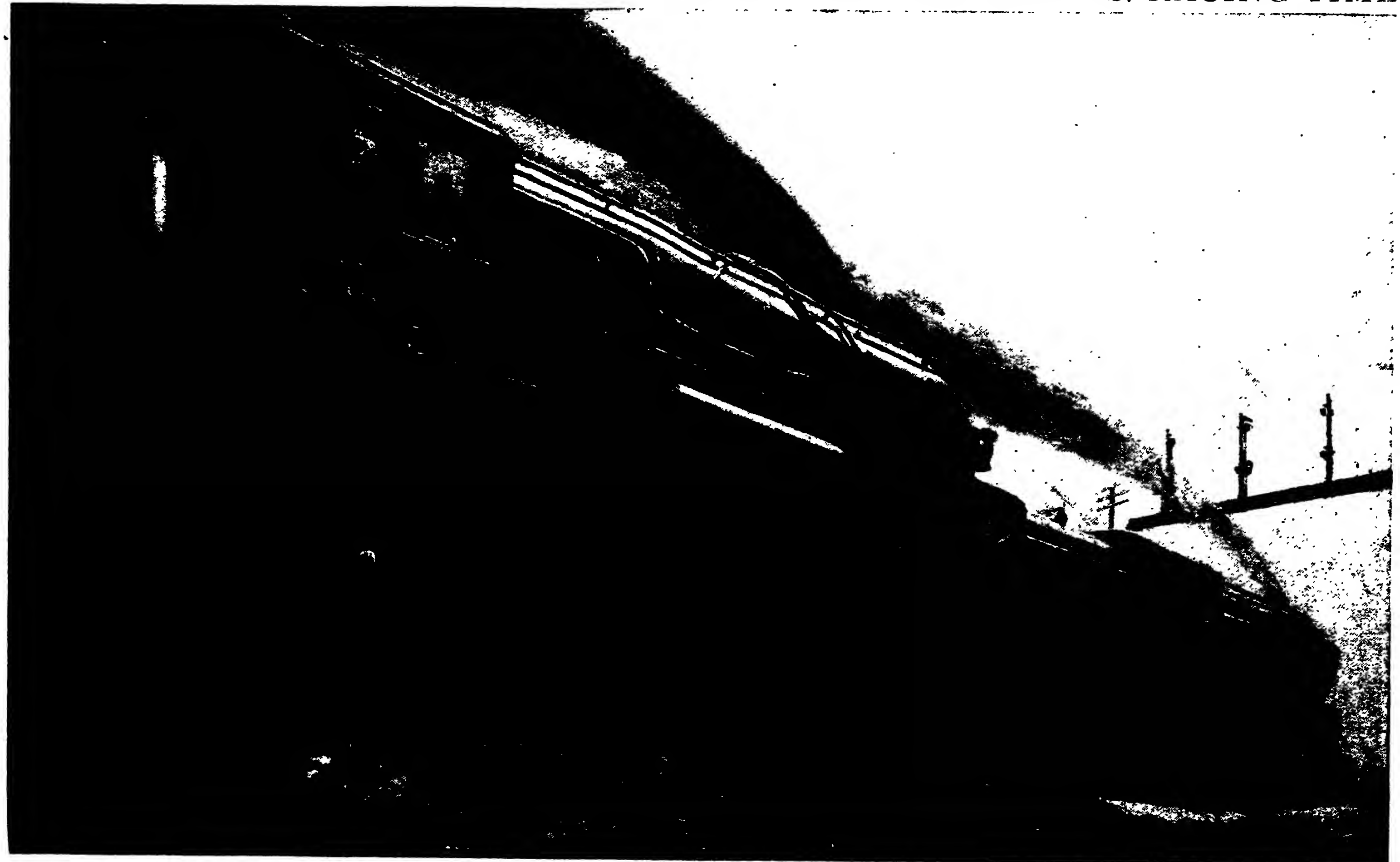
In the making of this longest railway line in the world, through an easy country—if the détour round the mountainous shore of Lake Baikal be excepted—every principle of sound railway engineering was broken, with the result that the line has failed constantly in its time of greatest need, and has cost an enormous sum in reconstruction. The fatal decision was made early that only Russian labour should be employed, and this was followed by a system of contract work which allowed room for the most barefaced peculation and inefficiency. The surveyors tried to bargain with the towns en route respecting the approach of the line, and punished the places that would not come to terms. As a consequence, scarcely a town on the whole route is really reached by the steel road—a disadvantage that is supposed to be a blessing by the people who earn a living conveying unfortunate travellers, often many miles, to and from the stations.

THE PATH-FINDERS WHO PRECEDED THE GRAND TRUNK PACIFIC RAILWAY

The specifications for the practical construction of the track were originally less exacting than would be demanded in the case of light railways in this country, but even then the conditions were not fulfilled. The width of the right of way through forest and plain, the breadth of the permanent way, the thickness of ballast, the weight of rails per yard, were all entirely inadequate, and they were further skimped wherever it was possible by the contractors.

As it has become clear that railway enterprise is not projected for the exclusive benefit of the people who happen to make the railway, but for the ultimate and lasting use of the inhabitants of the land and the travellers who pass that way, this great

THE MONSTERS THAT THUNDER ACROSS THE CONTINENTS, RACING TIME



RIVAL AMERICAN TRAINS COMPETING TO THE LAST OUNCE OF DRIVING POWER IN ORDER TO COMMAND THE THROUGH TRAFFIC

Siberian through route has been placed gradually on a more substantial basis, but at enormous cost in reconstruction, and loss in traffic that the resources of the country required to be handled, but that the railway failed to accommodate.

May 18 will be the forty-third anniversary of the opening of the first trans-continental railway that was ever constructed. It seems strange indeed to recollect that so far into modern times as 1855 men were going from one side of the United States to the other by way of Cape Horn, and for fourteen years from the opening of the Panama Railway in that year the crossing of the continent was by pony express. When the making of the overland railway was undertaken in earnest, by the Central Pacific Company, working from Sacramento in California, and the Union Pacific Company, working to meet th m from Omaha, their principal difficulties and perils arose from the persistent hostilities of the Indians of the Rockies.

Not only the pioneers who went out to discover a way for the railway, but the surveyors who planned the details of the track, and the engineers and navvies who made the line, worked with rifles ready to their hands. Indeed, it was while making a reconnaisance against the Indians that General Dodge, the chief engineer and generalissimo of the enterprise, discovered, accidentally, the Sherman Pass, through which the barrier of the Rockies was finally forced.

No wonder that the red man fought the railway with courage and tenacity. His instinct of resistance was sound enough, though more knowledge would have proved its hopelessness. The coming of the railway meant the going of the bison, and to the Indian the bison was the means of life.

Manifestly it would be unfair to criticise the engineering of the pioneer American trans-continental railway by the light of later days. Men were then learning how to make a railway of the first magnitude through a distant, unpopulated, and often desert land.

It is true the distance to be traversed was not so great as in the case of more recent ocean to ocean lines. It was only a mere 1500 miles. Already there was a busy railway and an active life for 140 miles between San Francisco and Sacramento on the western side; while in the east and middle districts a system of railway communication extended into Nebraska, which then was regarded as very far west. Still, the line making stretched into a very wild, lonely, dangerous, and unhelpful beyond, and its organisers had to learn by the making of mistakes.

Financially the inception of the scheme was unsound, if judged by a public standard, for not only did the United States Government subsidise the project at the rate of 16,000 dollars per mile across the plains, and three times as much per mile through the mountains, but they gave the company

"STATION-MEN" AT WORK MARKING OUT THE TRACK

half the land flanking the railway—a plan adopted later in Canada, but rejected by fuller experience, since it throws far too much power into the hands of the railway corporations.

The chief aims of the engineers on a great trans-continental line now are to lay down a track with as little rise and fall as possible, at an easy gradient all the way, with the minimum of mileage, or, in other words, the least possible curvature anywhere. The ideal line is straight and level. The first American line did not fulfil any of these conditions. A mile and a half of its course was more than seven thousand feet above sea-level; 56½ miles above six thousand feet; 182 miles about five thousand feet. A grading of 116 feet rise to the mile was permitted, whereas in the latest Canadian railway, the Grand Trunk, the slope has been restricted to 21 feet per mile. Such curvings to avoid supposed difficulties were allowed that in more recent times reconstructions have been undertaken which have cut off more than a hundred miles of the original route, while retaining a maximum grade of 21 feet to the mile.

None the less the original American overland route was a great accomplishment, and in the course of it the engineers met and mastered nearly all the difficulties that will be referred to when we sketch the progress of the Canadian through tracks—that is, the difficulties of interposed lakes, rapid streams, strong and weak mountains, bottomless bogs, avalanche-swept slopes, and snow-filled cuttings, with the usual want of labour, and doubt as to adequate capital. In addition, so much harassing warfare with the Indians was kept up that it was said the laying of every sleeper on the mountain section was at the cost of a shot fired at a lurking foe.

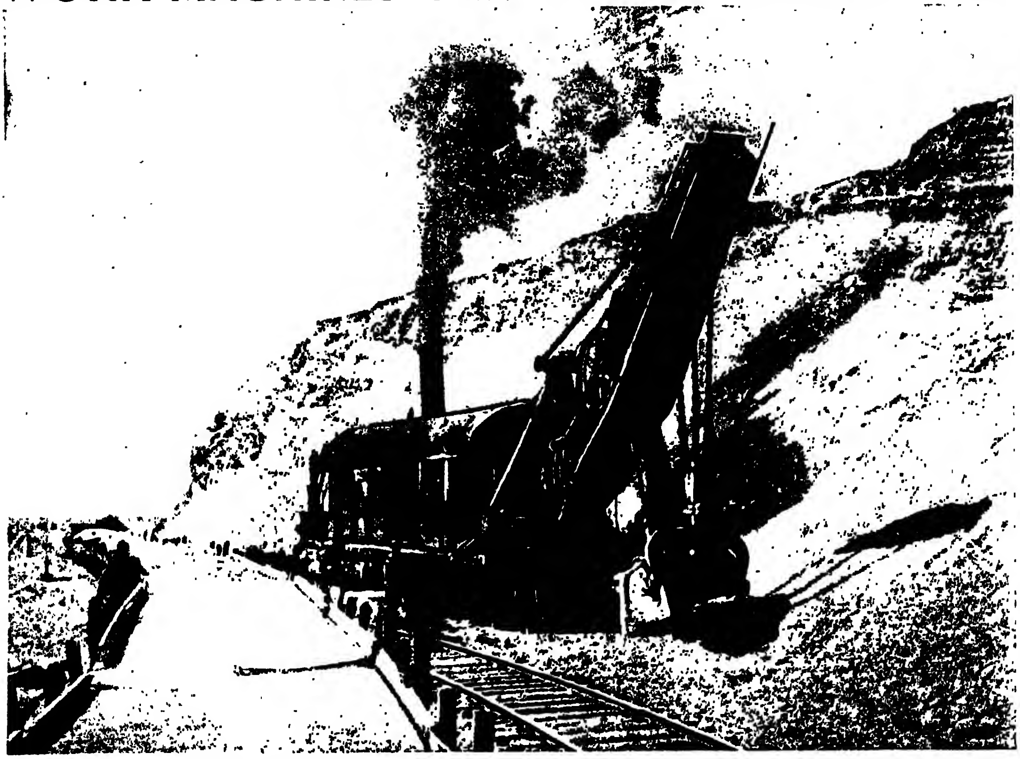
Considering all the circumstances, the distances to be traversed outside of any help from the country through which the construction gangs were passing, and the character of the country to be conquered, there can be no doubt that the greatest railway enterprise heretofore undertaken and accomplished by men has been the Canadian Pacific, joining Montreal with Vancouver. The mere distance, of 2906 miles, does not even hint at the story. No comparison can be made either with the first American track or with the Grand Trunk line, a fine engineering work now being forced rapidly through from Quebec to the Pacific coast. For, with the exception of the earlier part of the Grand Trunk, to the north of the Great Lakes, and the later part through the Rockies, this up-to-date enterprise has constantly been within comparatively easy reach of Canada's newly-founded western civilization and abounding business enterprise. It has passed from existing city to city at frequent intervals—Winnipeg, Prince Albert, and Edmonton—with opportunities of reinforcing itself from fresh bases. The American railway only covered half the distance, with great resources at either end. The Canadian Pacific had no such advantages. Before it, after Ottawa was left behind, was

A DOUBLE-ENGINED TRAIN CREEPING ALONG A NARROW MOUNTAIN LEDGE

LAYING THREE MILES OF RAILS A DAY

In the upper picture the "track-layer" is seen from behind, and from the front in the lower picture. In the latter sleepers are being passed forward, on the left, along a wheel-floored trough, while the crane has just dropped a steel rail, which is being hand-placed in position.

WORK MACHINES CAN DO AND CANNOT DO



A STEAM SHOVEL THAT SCOOPS UP AND LOADS THREE TONS OF EARTH AT ONCE

A GANG AT WORK ALIGNING RAILS AND SPIKING THEM TO THE SLEEPERS

BUILDING UP THE PERMANENT WAY

DISCHARGING EARTH FROM A CONSTRUCTION TRAIN TO BANK UP A TRESTLE BRIDGE

A TYPICAL STRETCH OF COMPLETED TRACK ON THE GRAND TRUNK PACIFIC LINE

a stretch of some 900 miles of "bad lands"—rocky, infertile, water-logged, abounding with difficulties, barren of resources. When the line emerged from rock and inhospitable forest, and reached the gateway of the great prairie lands, some distance short of Winnipeg, there was ahead 1000 miles of easy gradient, rising to the great central prairie plateau of 2000 feet elevation, but known only to the hunter and rancher, and entirely devoid of every form of supplies, whether of food, wood, or other material. Across the prairies loomed the most forbidding bastions of the Rocky Mountains, with the snowy Selkirk range behind that, and the Coast Range beyond, a prospect to daunt all except the most hopeful and fearless.

But it had to be grappled with at the price of a united Canada. Only on the obstacles to this gigantic scheme. The Government itself made and gave to the company the 700 miles of line through the unpromising and almost impenetrable rocky lands which separate the fertile east of the great Dominion from the fertile centre and west. Besides that, they made the company which eventually completed the line a loan of £6,000,000 sterling, and gave them a present of 25,000,000 acres—almost half the whole—lying astride the railway through the wide stretch of then untenanted prairie.

The nature of the country through which passed the part of the line made by the Government may be gathered from the fact that 12,000,000 dollars were spent on one section of 200 miles, and £400,000 worth of dynamite was used in blasting. It was necessary that this barely possible route

A LANDSLIDE IN SWAMPY COUNTRY BREAKING DOWN THE TRACK

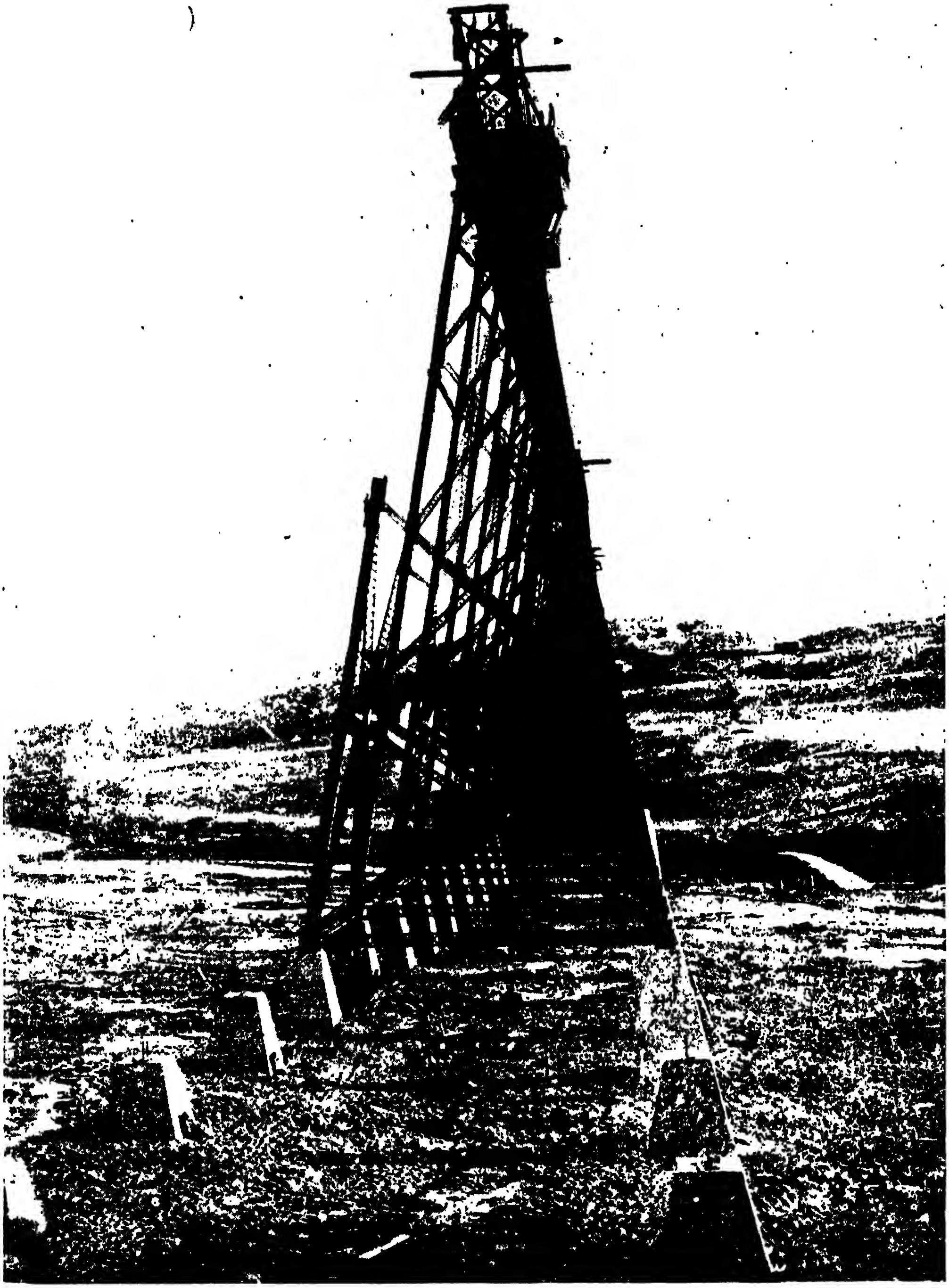
promise of a trans-continental Canadian railway would British Columbia, whose valleys, rich in minerals, run southward into the United States, agree to enter the Canadian federation. That conditional agreement to join with the eastern Canadian provinces was made in 1871, and surveying began in that year, but it was not until 1885 that the difficulties of the long journey were surmounted, and the steel track finally linked the Atlantic and the Pacific across British lands.

The enterprise never would have been carried through but for the splendid public spirit of the Canadian Government under the leadership of Sir John Macdonald. A bald statement of the help given—opponents said the bribes offered—by the Government will show how formidable were the financial should be followed in order that the line might skirt the northern shores of the Great Lakes, and so enable the future corn lands of the west to ship their grain at the north-western extremity of Lake Superior and secure a cheap outlet to the markets of the world.

One of the chief difficulties of railway-making in such regions as must be crossed while striking out a new route through a land like the Canadian Dominion, is the pioneering of the line of advance in trackless forests, alongside swift and treacherous streams, and over mountain passes, so as to preserve, in face of all obstacles, an easy gradient. To do this work successfully, thousands of extra miles must be surveyed, that the best of various possible routes may be chosen at last.

The story of the construction of the

BRIDGING A PRAIRIE VALLEY & RIVER



This Battle River viaduct on the Canadian Grand Trunk Railway is one and a half miles long and 180 feet high, and is an interesting example of keeping up the level by bridging.

latest Canadian line, the Grand Trunk, is told with vivid portraiture and unflagging spirit in a recent book, " The Making of a Great Canadian Railway," by E. A. Talbot. The Grand Trunk, when completed, will join the Atlantic with the Pacific across 3543 intervening miles. As with the Canadian Pacific, the Government is making the eastern part of the line—1801 miles to Winnipeg. It will then lease this section to the company for fifty years, at a three per cent. rental on the cost price. On the mountain section, too, in British Columbia, the Government guarantees first mortgage bonds for fifty years on 75 per cent. of the cost of construction, and pays the interest on the guaranteed bonds for the first seven years.

The special feature of the eastern part of the new Grand Trunk line is the attempt to get clear of the wilderness of rock and water that lies to the southward of the Great Lakes, and that proved such a costly barrier against the Canadian Pacific. By carrying the line well to the north, through New Ontario, it has been found possible to avoid much of the heavy work needed to blast a passage through the wilderness of rocks, and also to open up for cultivation a clay forest belt of great richness. Here, however, new obstacles arose, for the primeval forest, with its trackless confusion, densely covering a rich though unsunned soil, proved difficult to penetrate, or clear, or make firm for the weight of a railway.

Beyond the prairie, the Grand Trunk crosses the Rocky Mountains by the Yellowhead Pass to Prince Rupert, a route which enables the range to be surmounted at a height of only 3712 feet compared with 5329 feet at the summit of the Great Divide on the Canadian Pacific, and 8710 feet on the American Union Pacific.

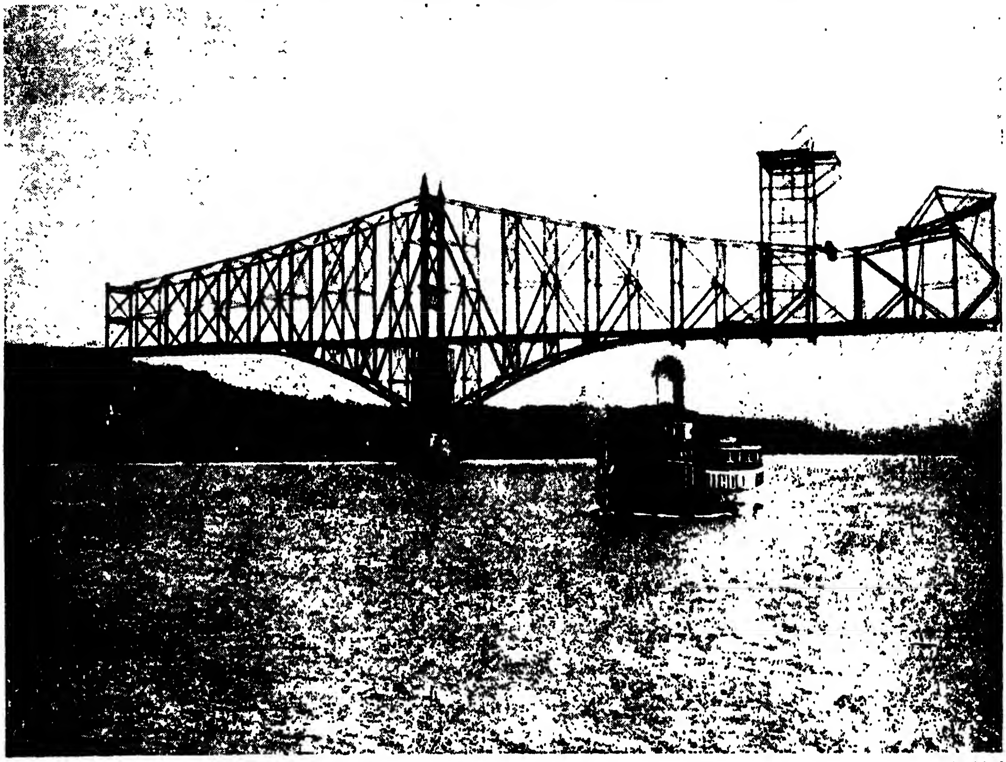
Originally the Canadian Pacific surveyors intended to take their line over the Yellowhead Pass, and then to follow the Fraser River down to Vancouver, but they put aside the plan for the more direct route up the Bow River, by the Great Divide, down the Kicking Horse Pass, and then over the Roger's and Eagle Passes—a heavy route demanding much snow-shed building, and trestle-bridge crossing of valleys from side to side, and involving a gradient on the Big Hill for 4½ miles of 232 feet per mile. The gradient here has since been reduced, but still the Big Hill remains a source of delay and of wasteful expense through the employment of several engines where one would serve on a route that had the standard gradient of not more than 21 feet to the mile.

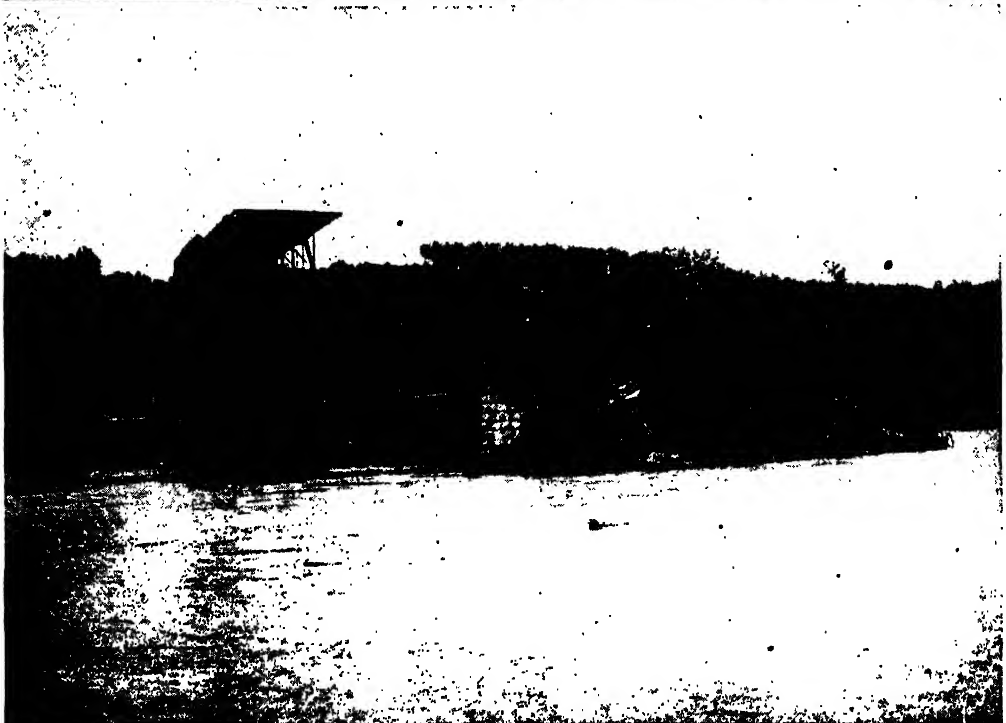
A RIVER IN FLOOD SWEEPING AWAY A GANGWAY USED IN BRIDGE BUILDING

The making of a railway across, say, the American Continent is a totally different enterprise from railway construction as understood in the British Islands. The line having been surveyed and pegged out, the grading, or levelling, of the track, the laying of the rails, and the ballasting are all done by machinery.

The first operation is the making of the track, embankment, or " dump," apart from the laying of the rails, and ballasting.

THE HUGE STEEL BRIDGE THAT FELL





The Grand Trunk Railway bridge over the St. Lawrence, at Quebec, was planned to be the largest steel bridge in the world, with a span of 1800 feet. When 800 feet had been constructed, as seen in the upper picture, it collapsed, as shown in the lower picture. Seventy-four lives were lost.

The engineers having gone ahead pegging out the "location," with a central peg every 100 feet, showing the middle of the track and the height to which it must be raised, and side-pegs giving the width of the embankment—14 feet—the graders or levellers follow. The grading machine—a sort of vertical ploughshare cutting off a layer of the earth—is drawn forward by horses, to the number of twenty sometimes, or driven by steam, and the topmost layer so scraped and dredged up is conveyed backward over the machine mechanically by buckets, and loaded into carts alongside, which convey from mounds and cuttings in the rear has to be carried on till a foundation is made, but often the line is carried forward first by a crazy trestle-bridge at the right level, and partly floated on a sunk faggot foundation only strong enough to just bear the passage of railway-waggons. The material for the embankment is then brought up from the rear in waggons with opening floors, and is shot down from the trestled bridge until the space below is filled up to the level of the line, the woodwork of the bridge being left buried to hold together and strengthen the embankment.

A LANDSLIDE WITH THE 100-FOOT-WIDE CLEARING FOR THE RAILWAY SHOWN ABOVE

it to the "dump," or embankment that is following along the level track made by the grading machine. As far as possible on the prairies the track is made without cuttings, so as to prevent accumulations of snow in the winter.

One of the great difficulties of all railway construction across the American continent has been the presence of "muskegs," or partly dried up lakes or bogs, that do not give a sufficiently good bottom for the embankment; or, again, there are depressions of a level character that have to be crossed. In such cases the tipping of earth and rock

Where cuttings must be made, or mounds be removed for ballast, or to clear the way the steam navvy, of course, is in constant use, taking its crunching bite of three tons of earth at a time, and dropping it into a waggon alongside. It is when the level "dump" has been roughly made, to the height indicated by the stakes of the engineers, that the most striking evidence of labour-saving and time-gaining ingenuity is to be seen, in the track-laying machinery.

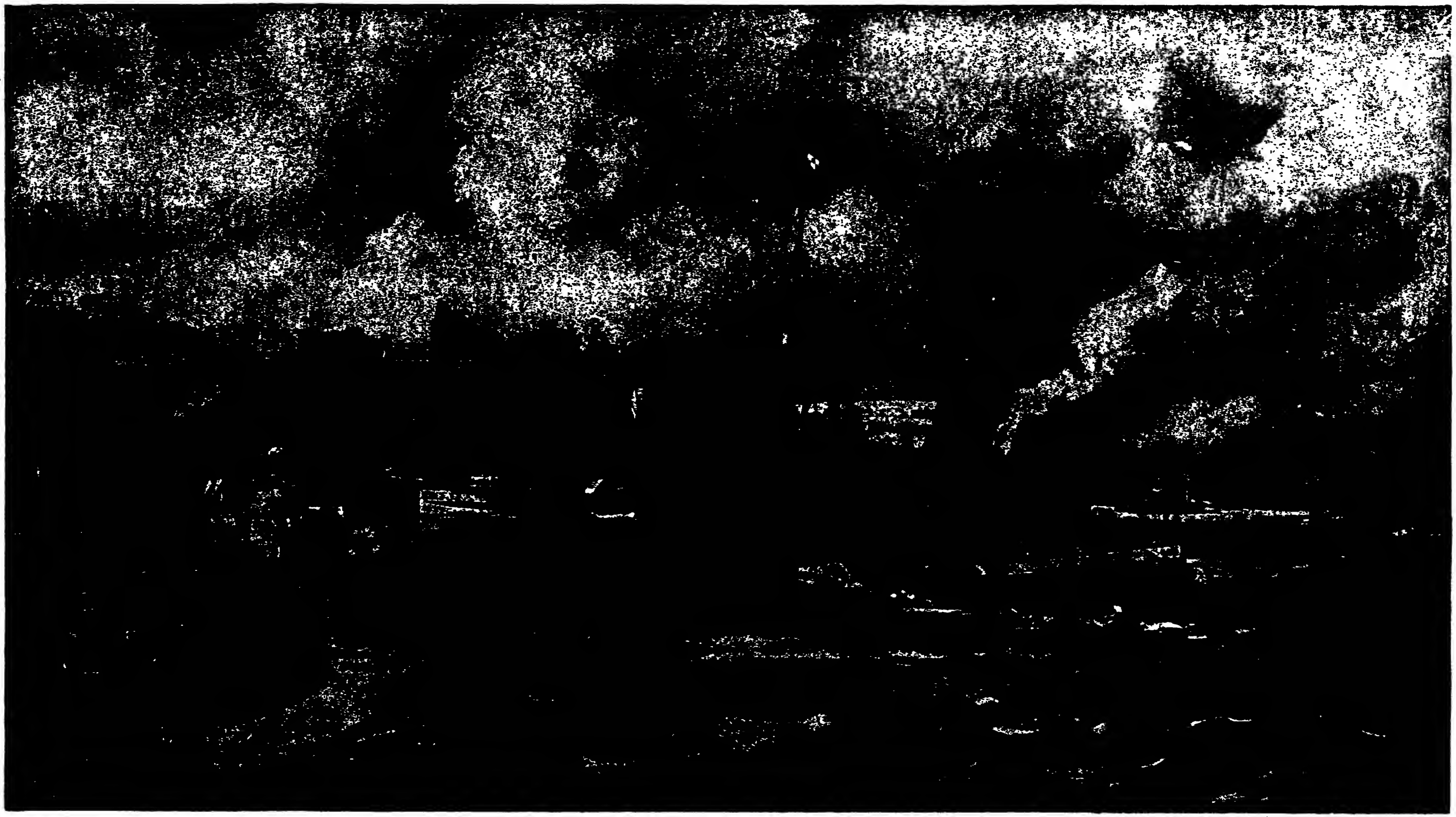
The track-laying machine is a whole train. The engine pushes before it in the foremost position the track-laying truck, carrying

elaborate machinery for cranework. Behind this truck are others loaded with rails, bolts, and spikes; and behind the engine, more trucks loaded with railway-sleepers, or "ties," as they are called in the Western world. Alongside the train, at the height of the waggons, runs a mechanical conveyer, or trough with rollers in its bed, and this is projected some forty feet in advance of the track-layer. Along this conveyer, with its resistless rollers, the sleepers are conveyed to the front of the train from the rearward waggons, and are tumbled out alongside the lines to be picked up by men, and placed at measured distances across the track. The track-layer then swings forward and lowers a couple of thirty-foot rails, which are spiked to the sleepers just now arranged on the "dump," and the train passes forward at once over the rails that have just been laid, and repeats the process with a fresh pair of rails. In this way from two to three miles of rails can be laid in a day. About 150 men are needed to work each of these track-laying trains—feeding the conveyer with sleepers, arranging the sleepers on the track in front of the train, and placing and fastening the steel rails.

The line is now, of course, in a very crazy and irregular state, and is only suited for the slow movements of construction trains. It remains to be ballasted. This, too, is done mechanically. A ballast train discharges its load through the floors of its waggons, and then at the end of the train comes the ballast distributor, which levels the surface at the required height with mechanical accuracy. The railway is still not fully made. It has to be aligned and raised to its exact height, length by length of rail, and to be constantly watched for settlements till it is steadily bedded, and capable of carrying express traffic safely. By the use of such methods as these, following on the fine organisation of its elaborate system of railway camps and supply service, the Canadian railway service keeps its constructional work on a level with the boldness of spirit and faith in enterprise which have planned and financed the great network of communications that is so swiftly developing every part of the Dominion. Through its railways Canada lives and grows. Everywhere the story is the same—the railway is the secret and the sign of prosperity.

THROWING THE RAILWAY ACROSS THE BAYS OF THE SHEENA RIVER TO SAVE CURVES

A LEVIATHAN CARRIER OF COMMERCE BETWEEN THE HOMELAND AND CANADA



ARRIVAL AT HISTORIC QUEBEC OF A GREAT OCEAN LINER BRINGING THE MANUFACTURES OF GREAT BRITAIN TO THE MARKETS OF THE WEST

THE SHIPPING OF THE WORLD

The Growth and Expansion of the Chief Instrument of International Commerce

HOW BRITAIN STILL RULES THE WAVES

It is quite a small number of men who are needed to conduct even a very great shipping. The United Kingdom possesses a mercantile marine which is gigantic in its proportions, but only a tiny fraction of the British population is directly concerned in its working. The overwhelming majority of us are landsmen, largely indifferent, it is to be feared, by reason of our own cares and preoccupations, to the lives and labours of those who go down to the sea in ships. So it falls out that in spite of reiterated assertions as to Britannia's relation to the waves, few indeed in our island nation appreciate the enormous part played in the world by British shipping, and how much we owe, whatever our callings or professions, to its existence and its superiority.

Through many changes, during long years past, the maritime supremacy of Britain has remained. The coming of oil-fuel may work to the disadvantage of the United Kingdom, because we have much native coal, but no native oil, but so far we have kept an almost incredible degree of mastery, as iron has beaten wood, and as steam has beaten sails.

At the present time at least one hundred million pounds sterling, and probably much more, are earned every year by the ocean ships of the United Kingdom. Our mercantile marine carries not only the greater part of the seaborne trade of the United Kingdom, but no small part of the sea-carrying trade of the entire world. Indeed, income is earned for the United Kingdom even by ships which never ply to her shores, but which carry between foreign ports only.

The supremacy of British shipping is the result of taking advantage of British natural gifts. An island race should naturally be a maritime people, and the British Isles are obviously situated in a position of advantage for sea traffic. Position, however, is not the only explanation of British sea-power. For France and Spain are just as well situated. The latter two nations have mercantile marines of considerable dimensions actually, but relatively to British sea-power their united shippings appear exceedingly small.

Added to an excellent geographical position and fine ports, the United Kingdom, as we have already seen, has some of the best-known supplies of coal, placed by Nature near to good ports. This has much to do with the later developments of British shipping. Since the industrial revolution began, and the United Kingdom became a great importer of food and raw materials, coal exports, affording good outward cargoes, have served to balance the bulk of imports and exports from the shipowners' point of view, and to make British shipping profitable. Coal exports have enabled a large proportion of our ships to earn freights both inwards and outwards, with advantage not only to shipowners, but to the purchasers of foods and materials, who, if sufficient outward shipments did not exist, would have to pay in effect for the working of a ship both inwards and outwards. It is thus a very great part which coal exports have played in British mercantile progress. With imports and exports freely exchanged, we need not wonder if British shipping records look exceedingly healthy.

Let us see how Britain stands in the world of shipping; and before we come to look at the available records let us remind ourselves how ships are measured. A ship is said to be of so many "tons," either "gross" or "net." "Gross tonnage" is the solid contents of a vessel expressed in "tons" of 100 cubic feet. A ton of shipping is thus a *measurement* ton, and not a ton by weight. The "net tonnage" of a vessel is the gross tonnage, less a certain deduction made for

"crew space" in the case of sailing-ships, and a further deduction for the space occupied by engines and boilers in steamships.

It is in "net" tonnage that the facts in the statement on this page are expressed. Here we have a clear expression of the shipping progress of the world during nearly thirty years, 1908 being the latest year for which figures for all these countries are available. All the principal maritime nations are included in the table, and the remaining ships are negligible by comparison.

The first point to which attention should be directed is the decline of the sailing-vessel. In 1880, there were nearly fifteen million tons of sailing-vessels possessed by the countries named, which own nearly all the ships of the world. Twenty years later, in 1900, sailing-vessels had declined to ten million tons. Eight years later, in 1908, there were less than nine million tons.

The progress of the steamship has been even more remarkable than the decline of the sailing-vessel. In 1880, there were less than six million tons in the world; in 1900, there were over sixteen million tons; in 1908, there were about twenty-five million tons. It was in the early 'eighties of the nineteenth century that the construction of steamships took the lead; and when we remember that a steam-ton is the effective equivalent of three sailing-tons, we see how enormous must have been the development of commerce in the last generation. When we say that in thirty years the world's steam tonnage has increased by about 20,000,000 tons, this means that it has increased by the equivalent of 60,000,000 tons of sailing-ships. As, in the same time, the decline of sailing-ships has been 6,000,000 tons, we get the result that, expressed in the equivalent of sailing-tons, *the world's ships have grown by about 54,000,000 sailing-tons in only thirty years.*

And with all this progress the United Kingdom has held an astonishing supremacy. Whereas in 1880 she had about six and a half million tons of shipping, in 1908 she possessed eleven and a half million tons.

THE ASTONISHING STRENGTH OF THE WORLD'S MERCHANT NAVIES

Countries	1880		1900		1908	
	Sail and Steam	Steam Only	Sail and Steam	Steam Only	Sail and Steam	Steam Only
	Tons	Tons	Tons	Tons	Tons	Tons
United Kingdom	6,575,000	2,723,000	9,304,000	7,208,000	11,541,000	10,139,000
Canada	1,238,000	100,000	639,000	164,000	703,000	296,000
Newfoundland	87,000	6,000	112,000	10,000	147,000	15,000
Australia	210,000	59,000	333,000	190,000	386,000	256,000
New Zealand	64,000	12,000	99,000	57,000	152,000	107,000
India and Ceylon	89,000	12,000	76,000	43,000	107,000	86,000
British Empire (including parts not named above)	8,447,000	2,949,000	10,751,000	7,740,000	13,263,000	10,980,000
German Empire	1,181,000	216,000	1,942,000	1,348,000	2,825,000	2,302,000
United States:						
(*a*) Oversea	1,353,000	147,000	827,000	341,000	940,000	599,000
(*b*) Lake and Coasting	2,715,000	1,065,000	4,338,000	2,316,000	6,425,000	4,112,000
Japan	89,000	41,000	864,000	543,000	1,544,000	1,160,000
France	919,000	278,000	1,038,000	527,000	1,452,000	804,000
Norway	1,519,000	58,000	1,508,000	505,000	1,570,000	851,000
Italy	999,000	77,000	945,000	377,000	1,020,000	567,000
Spain	560,000	234,000	775,000	679,000	743,000	688,000
Holland	328,000	64,000	347,000	268,000	458,000	414,000
Denmark	249,000	52,000	408,000	250,000	541,000	405,000
Russia	468,000	89,000	634,000	364,000	701,000	443,000
Sweden	543,000	81,000	614,000	325,000	611,000	439,000
Belgium	76,000	65,000	113,000	112,000	152,000	149,000
Austria-Hungary	300,000	71,000	265,000	239,000	497,000	447,000
Greece	200,000	20,000	319,000	143,000	441,000	295,000
Finland	288,000	11,000	341,000	54,000	383,000	69,000
China	22,000	22,000	39,000	18,000	76,000	58,000
Portugal	80,000	30,000	109,000	52,000	80,000	42,000
Grand Total (nearly all the world's ships)	20,336,000	5,570,000	26,177,000	16,201,000	33,722,000	24,824,000

This is to lump steam and sailing ships together, but we get a truer idea of British maritime advance if we consider steam tonnage alone. This is done in the following figures.

THE WORLD'S STEAM TONNAGE

—	1880	1900	1908
United Kingdom ..	2,700,000	7,200,000	10,100,000
Rest of the world .	2,900,000	9,000,000	14,700,000
All the world (a few unimportant items excepted)	5,600,000	16,200,000	24,800,000

We see that, in 1908, out of 24,800,000 steam-tons possessed by nearly all the world, the United Kingdom owned as many as 10,100,000 tons.

And even this is an under-statement of Britain's real position. It will be readily understood that there are tons and tons, even among steam vessels. The best and the fastest vessels of the world are chiefly owned by British shipowners, so that in tons effective the United Kingdom possesses a larger proportion even than is shown in the above figures, good as they seem without further examination.

There is another consideration of importance in this connection. It is that the above record includes all the ships of the United States. The greater part of these, however, are vessels which ply only in the Lake and coasting trades of America. If we rule out these, America has a very small mercantile marine engaged in ocean traffic. The United States possesses only about 600,000 steam-tons, and less than one million steam and sailing tons, engaged in ocean commerce. If we include these only, to get a proper comparison, we obtain the following record of the leading maritime powers in 1908.

THE LEADING MARITIME POWERS, 1908

Country	Steam Tons Only	Steam and Sailing Tons
United Kingdom	10,139,000	11,541,000
Germany	2,302,000	2,825,000
Japan	1,160,000	1,544,000
Norway	851,000	1,570,000
France	804,000	1,452,000
Spain	688,000	743,000
United States (ocean ships only)	599,000	940,000
Italy	567,000	1,020,000
All other nations	3,590,000	5,665,000
Grand Total (nearly all the world's steamships)	20,700,000	27,300,000

There are only eight nations in the world which possess over half a million tons each of ocean steam shipping, and these are, in the order of their importance, the United Kingdom, Germany, Japan, Norway, France, Spain, the United States, and Italy. All the rest of the world put together possess only about three and a half million steam-tons, making, with the eight countries named, less than twenty-one million tons. Of these nearly one-half are the property of British shipowners, which means that in effective tonnage the United Kingdom possesses *much more than one half* of the steamships of all the world, including her own Colonies and Dependencies.

Germany is second in the race, but she is a poor second in this respect to Britain, as will be seen. Nevertheless, we have to remember that she has a very poor seaboard, and nothing like the natural advantages for shipping which are possessed by, say, France or Spain. Her position, indeed, as compared with other countries, and especially as compared with the United States, is exceedingly creditable. Germany has fostered her shipping with great solicitude; and the fact that she ranks next to the United Kingdom is another proof of her genius and of the determination with which she faces even inherent disadvantages. Her statesmen realise what sea-power means in a world which is disunited by the sea, and, so far, can be only united by the ship.

The wonderful rise of Japanese shipping will be realised from the table on page 1476. As recently as 1880, Japan possessed a mere forty thousand tons of steamships; in twenty-eight years this paltry figure had been swollen to 1,160,000 tons, raising Japan to the position of the third maritime nation in the world. It has been a sensational advance. It was sea-power which gave Japan the advantage in the Russo-Japanese War, illustrating once more for how much sea-power counts in the world, and in the making of the history and nations.

The United States occupies what can only be described as a position in the list which is quite unworthy of her. That the United States should have on the ocean only about one-half as many ships as Japan would seem incredible if we were not assured of its truth. The fact is, of course, that the United States has pursued a policy of restriction in commerce which has a profound effect upon her trade and shipping. It is a striking instance of how natural advantages can be misused. The United States occupies one of the most

advantageous positions in the world. She has two magnificent seaboards, and good harbours, and a central position in the world of commerce, fronting the two great oceans. Moreover, as she is the greatest iron and steel nation, she has natural superiority in shipbuilding, for modern shipbuilding really consists of several branches of the iron and steel trade. She has been content to forgo a great shipping on the ocean, although on the Great Lakes and in her coasting trade she has, of course, a considerable number of vessels employed. The curious decline of American ocean shipping is shown in the following record.

DECLINE OF THE AMERICAN OCEAN SHIPPING

Year	Steam and Sailing Ships		Steamships Only	
	Coast and Lake	Ocean	Coast and Lake	Ocean
	Tons	Tons	Tons	Tons
1850..	1,899,000	1,586,000	481,000	45,000
1860..	2,753,000	2,546,000	771,000	97,000
1870..	2,678,000	1,517,000	883,000	192,000
1880..	2,715,000	1,353,000	1,065,000	147,000
1890..	3,478,000	947,000	1,661,000	198,000
1900..	4,338,000	827,000	2,316,000	341,000
1908..	6,425,000	940,000	4,112,000	599,000

In 1860 the United States had on the ocean 2,546,000 tons of shipping, against 4,658,000 possessed by the United Kingdom. Between 1860 and 1870 there came the Civil War, and from that time the ocean figures have declined.

We must not expect this position to continue indefinitely. Sooner or later the American people will make full use of their maritime advantages, and the beginning of the change will probably be seen with the opening of the Panama Canal in 1915 or 1916. That great engineering feat will work greatly for America's commercial advantage, and it will be strange indeed if American shipowners do not profit by the enterprise of their own Government. If and when American shipping develops, British shipowners will, more than others, feel the change, by reason of their present extraordinary supremacy. There can be no possible doubt that it is partly due to the supineness of the United States in shipping matters that we have acquired such a strong maritime position. We have, indeed, been doing for America much of the carrying work which she might have done for herself, and which some day she will do for herself.

How important these considerations are will have been gathered from preceding chapters. The services of our fine ships are in very truth "exports," which earn imports for us just as truly as though we sent out goods. Either by estimating the earnings of ships on the basis of tonnage, or by a deduction from the total value of the world's commerce, we can arrive at an approximate idea of what our ships earn in the course of a year.

The latter method is an exceedingly simple one. If we take the imports and exports of all the principal countries of the world, we find that the imports exceed the exports in value. Why is this? Obviously, the imports and exports are the *same goods*, entered as "exports" by the countries which send them out, and as "imports" by the countries which bring them in. The explanation is that, as a general rule, goods exported are valued by Custom Houses at their price as sold, and before they are increased in value by transport to their destination in the importing country. On the other hand, when the goods arrive at their destinations as "imports," they are valued at the Customs with the addition of the cost of their transport (c.i.f., or cost, plus insurance, plus freight).

Thus if a locomotive costing £3000 is exported from London to Buenos Aires, and the freight and insurance charges come to £300, then in the British trade returns there appears an "export" of £3000 worth, and in the Argentine trade returns there appears an "import" worth £3300. That is why the imports of all countries, added together, come out at a bigger figure than the exports of all countries added together, although they relate to the same goods.

If we aggregate the imports and exports of most of the countries of the world as given in the last chapter, we find that the imports aggregate 3409 million pounds, while the exports aggregate 3141 million pounds. So the imports exceed the exports thus:

	£
Imports	3,409,000,000
Exports	3,141,000,000
Imports exceed exports by	£268,000,000

Approximately, therefore, the transportation of the goods concerned—as we may say, the transmutation of "exports" into "imports"—cost £268,000,000. This sum, roughly, was earned by all the world's ocean-going ships.

But, as we have seen in this chapter, the

United Kingdom owns about one half of all the world's ocean-going ships. Therefore we deduce the estimate that British ships earn approximately £130,000,000 in a year. In a former chapter we named a rather smaller figure than this for safety, and, of course, it is not possible to estimate the figure with exactitude. It is perfectly clear, however, that the British mercantile marine is amongst our most valuable commercial and industrial assets.

We have remarked that the number of persons employed in the mercantile marine account for but a small proportion of our population of forty-five millions. The facts of the case are that all the ships belonging to the United Kingdom, excluding only vessels employed on rivers and canals, whether employed in the coasting or foreign trades, and including fishing-vessels, find employment for about 200,000 British seamen, 35,000 foreign seamen, and 45,000 Lascars and Asiatics, many of whom are British subjects. These figures include the masters and other officers of vessels.

And, owing to the growth of steamships, the number of men employed has not grown with the increase of shipping. If we take the three years 1880, 1900, and 1908, we find that the growth of seamen has been :

BRITISH MERCANTILE MARINE : GROWTH OF PERSONNEL

Year	British Seamen	Foreign Seamen	Lascars and Asiatics	Total
1880 ..	169,692	23,280	not known	?
1900 ..	174,532	36,893	36,023	247,448
1908 ..	196,834	34,745	44,152	275,721
Increase in 28 years	27,142	11,465	?	?

So that an enormous increase in shipping has been worked, through the progress of navigation, by a slightly increased number of men. The possession by Britain of such a great carrying trade is a natural stimulus to the shipbuilding industry. British shipyards find in British shipowners a magnificent home market, and they are able, in addition, to command valuable markets abroad. The British lead in shipbuilding is even more remarkable than the British lead in shipowning. When one first becomes acquainted with the nature of the case, one is inclined to doubt the facts, so wonderful do they appear.

In 1911 British shipyards built *two-thirds of the ships built in all the world.* Here, in these little islands, we construct over 2,000,000 tons of shipping in a year.

The deeply interesting shipbuilding record of the last twenty years is given in the table on the next page, and for many reasons it will repay careful examination. We have stated figures for all the world, the United Kingdom, Germany, the United States, and France respectively.

The first thing to observe is that, in each of the twenty years shown, British shipyards constructed most of the ships built, and usually something like two-thirds of the whole. Watch the ships pass through the Suez Canal, and you will find that most of them fly the British flag. From the annexed statement something more than that will be realised, and it is that a large proportion of the vessels which do not fly the British flag were constructed in British shipyards. We get a picture of British shipyard workers constructing the vessels that carry the greater part of the wonderful trade of the world.

It is not necessary to dwell upon the figures of Germany, America, and France, which are insignificant by comparison with ours. It is more important to direct attention to another vitally important consideration which is brought home to our minds by this record of shipbuilding. It is the variability and fluctuation of trade to which it points. Whether we look at the British, the German, the American, or the French figures, or whether we take the figures of the whole world, we see wide fluctuation from year to year, and sometimes fluctuation of a most extraordinary character in the space of a short twelve months.

Look, for example, at the years 1907, 1908, and 1909. In 1907, 2,778,000 tons of ships were built in all the world ; next year the tonnage built in all the world fell to 1,833,000 tons, and in the year following there was a further fall to 1,602,000 tons. This, of course, was the result of the wave of depression that swept over the whole world of commerce in 1908–9 ; there was a "slump," to use a familiar term. We get these slumps pictured in the shipbuilding industry in an exaggerated form, for the simple reason that the industry is engaged in making an instrument of commerce, and that it feels, as it were, a concentration of the depressions of all other trades. If we consider what this means to the men who construct ships, we have something to give us pause. In 1907, about 2,800,000 tons constructed ; in 1908, about 1,800,000 tons constructed ; that means a

WHERE THE MERCHANT SHIPS OF THE WORLD ARE BUILT

Year	United Kingdom	Germany	United States	France	All the World
	Tons	Tons	Tons	Tons	Tons
1892	1,110,000	65,000	63,000	17,000	1,358,000
1893	836,000	60,000	27,000	20,000	1,027,000
1894	1,046,000	120,000	67,000	20,000	1,323,000
1895	951,000	88,000	85,000	29,000	1,218,000
1896	1,160,000	103,000	184,000	45,000	1,568,000
1897	952,000	140,000	87,000	49,000	1,332,000
1898	1,368,000	153,000	173,000	67,000	1,893,000
1899	1,417,000	212,000	224,000	90,000	2,122,000
1900	1,442,000	205,000	333,000	117,000	2,304,000
1901	1,525,000	218,000	433,000	177,000	2,618,000
1902	1,427,000	214,000	379,000	192,000	2,503,000
1903	1,191,000	184,000	382,000	93,000	2,146,000
1904	1,205,000	202,000	238,000	81,000	1,988,000
1905	1,623,000	255,000	303,000	73,000	2,515,000
1906	1,828,000	318,000	441,000	35,000	2,920,000
1907	1,608,000	275,000	475,000	62,000	2,778,000
1908	930,000	208,000	304,000	83,000	1,833,000
1909	991,000	129,000	210,000	42,000	1,602,000
1910	1,143,000	159,000	331,000	81,000	1,957,000
1911	1,804,000	255,000	172,000	125,000	2,650,000

decline in employment in all the world's shipyards, in a single year, in the ratio of 100 to 64 (about). That means, of course, that where in 1907 there was work for 100 shipyard workers, in 1908 there was work for only 64. That means no work in 1908 for one out of three of the men who were at work in 1907; and in the following year the number fell again. After that came revival, and in 1911 complete revival.

Such are the facts we have to face in industry and commerce at the beginning of the second decade of the twentieth century. Such are the disharmonies and imperfections which still bring sorrow and poverty and distress to millions of industrial workers throughout the world every few years.

House-building, engineering, and some other trades suffer quite as much as shipbuilding, and practically all trades suffer these fluctuations in some degree. The problems created by these fluctuations are at last beginning to engage the attention of the Governments of the great nations; and, it will be gathered, not too soon.

The statement we have just considered excludes warships. If we add war-vessels, British shipyards in 1911 constructed no less than 2,034,630 tons of shipping. Let us see where the customers of British shipyards are found. The facts on this head are given in the table on the next column.

Thus, in addition to building 1,399,770 tons for the British mercantile marine, and 221,430 tons of British warships, British shipyards, in 1911, constructed 404,074 tons for foreign mercantile marine and 9356 tons of war-vessels for foreign Governments. Amongst our biggest customers, Norway, the British Colonies, Austria-Hungary, Holland, Germany, South America, and Sweden are prominent.

BRITISH SHIPBUILDING IN 1911: OUR CHIEF CUSTOMERS

Countries	Tonnage (including warships)
United Kingdom	1,399,770
British Colonies	59,974
Austria-Hungary	51,157
Denmark	15,330
France	16,960
Germany	20,527
Greece	12,963
Holland	26,665
Italy	9,372
Japan	19,814
Norway	89,889
Russia	13,450
South America	27,835
Sweden	18,675
Total (above and other countries)	1,803,844
Add Warships:	
(*a*) Built for British Government ..	221,430
(*b*) Built for Foreign Powers	9,356
Grand Total for 1911	2,034,630

For some countries we build more ships than they build for themselves. For example, in 1911 British colonies built less than twenty thousand tons for themselves and bought nearly sixty thousand tons from us; Austria-Hungary built less than forty thousand tons herself, and bought over fifty thousand tons from us; Norway built only thirty-five thousand tons for herself, and bought nearly ninety thousand tons from us. The same is true of some other nations. Altogether, it is a proud position which is held by British shipbuilders.

The distribution of the shipbuilding industry in the United Kingdom presents some points of interest. For the most part it is carried on near coal-mines, and especially where good ports are near coal-mines. The construction at the ports which are the chief seats of the industry is shown in this statement, which covers the greater part of the British shipbuilding of 1911:

WHERE BRITISH SHIPBUILDING IS CARRIED ON: 1911

District	Merchant Vessels		War-ships	Total
	Steam	Sail		
	Tons	Tons	Tons	Tons
Aberdeen ..	8,811	—	—	8,811
Barrow, Maryport, and Workington ..	1,328	300	36,740	38,368
Belfast ..	180,547	—	—	180,547
Dundee ..	12,733	2,649	—	15,382
Glasgow ..	321,308	12,752	74,166	408,226
Greenock ..	207,301	—	—	207,301
Hartlepool & Whitby ..	135,557	—	—	135,557
Hull and Grimsby ..	37,194	—	—	37,194
Leith ..	11,887	—	—	11,887
Liverpool ..	22,147	—	5,160	27,307
Middlesbro' & Stockton ..	140,422	1,512	—	141,934
Newcastle ..	411,479	1,480	28,120	441,079
Sunderland ..	286,828	—	—	286,828

It will be observed that London does not appear in this list; that is because of the marked effect of situation upon the economics of wealth production. Although London is a great port, and ship-repairing must necessarily be done there, shipbuilders on the Thames cannot compete for economic reasons with the Northern shipyards, or at least they appear to have the greatest difficulty in doing so, whether in regard to ships for the mercantile marine or ships for the British Navy.

Where there is considerable concentration of shipbuilding at a great port, as at Glasgow, Greenock, Newcastle, or Sunderland, the distress from the fluctuations, which we have already seen to be an accompaniment of industry, is very severely felt, owing to the considerable number of shipyard workers amongst the populations of the towns.

The selection of shipbuilding as one of the trades to be compulsorily insured against unemployment under the National Insurance Act of 1911 will be readily understood from the facts which have been adduced.

It will have been gathered from our survey of shipping and shipbuilding that while the United Kingdom plays so large a part in them, the British dominions and possessions have not yet developed either mercantile marines or shipyards of any great importance.

All the British Empire, outside the United Kingdom, owned in 1908 only about 850,000 tons of steamships, chiefly possessed by Canada and Australia. In the time to come we may expect to see these figures very largely increased, for many of the British dominions are well situated for commerce, and have excellent seaboards and fine ports.

As to shipbuilding, success depends upon the possession of a naturally great iron and steel industry, now that the day of the wooden ship has passed for ever. In former chapters we have surveyed the probabilities of successful Colonial industrial expansion; and we may conclude from the available evidence that successful shipbuilding on a large scale may come to be prosecuted at some of the Colonial ports.

There are, of course, great possibilities of change in the future of the world's shipbuilding, not only because of changing currents of trade and of new power-developments, but because of the new and rapid development of another form of transit. The possibility of a complete revolution in transport through the conquest of the air can no longer be considered an idle dream. If such changes come, the sea may be robbed of a great part of its present function as the chief medium of the world's commerce. The prospect may be regarded with equanimity by those who have not realised the swiftness of economical changes depending on invention, but it is for an island nation to be awake to the grave consequences such developments would entail for islanders.

THE REIGN OF LAW IN THE MODERN WORLD

AS SOCIETY CONSOLIDATES IT WELCOMES FORMAL LAWGIVING, THOUGH NOT WITHOUT FEAR

This painting, by Mr. Edwin H. Blashfield, in the Youngstown Court House, Ohio, representing the reign of modern law, is from a photograph by Mr. Peter Juley, by courtesy of Messrs. Owsley, Boncherche, and Owsley, architects.

THE EVOLUTION OF SOCIETY

The Social Group as a Living Thing that Develops According to the Laws of Life

THE FAILURE TO MANUFACTURE NATIONS

SINCE the United States drew up its Constitution on paper, a considerable number of nations have been manufactured in a similar way. One of our greatest political philosophers, Jeremy Bentham, used to hold himself ready to create States at a moment's notice. In his days it was thought that a higher and better form of society could easily be manufactured by destroying the traditions of a people and drawing up for them a new set of political arrangements and laws.

For about a hundred years the manufacture of advanced Constitutions for backward races was a favourite pursuit of European political thinkers; and the idea still widely obtains that by giving a people a new form of government on paper a remarkable improvement in their social and political life can suddenly be effected. Races in the Balkans, formed in communal families and village communities, and ripe for a paternal government, like that of Montenegro, have been given a Parliament and a Constitutional monarchy, somewhat after the British pattern. Nations of Redskins and half-breeds in Central and Southern America, that were ready for a strong but enlightened and sympathetic despotism, have been fitted with congresses and presidents, after the model of the United States. Here and there, perhaps, a people has apparently managed to live up to the strange new machinery abruptly placed in its hands, but, on the whole, the ideas of the great political thinkers have been sadly degraded in actual practice.

Thrusting a semi-barbaric race into the institutions of free government does not suddenly elevate it, any more than dressing a boy in man's clothes gives him the strength and intellect and stature of a man. A boy in man's clothes is merely ridiculous and awkward; a nation with a Constitution too advanced for it becomes only a parody of a highly civilised State. Many of the Republics of Central and Southern America are caricatures of the United States, for the same reason that several of the small nations of the Balkans are caricatures of the Constitutional monarchies of Europe.

Certainly some nations seem to have benefited by a new paper Constitution, which suddenly changed the entire complexion of their social and political life. Japan is an instance in point. But, as a matter of fact, the fabric of Japanese government has not been recast after the European model. Instead of throwing aside all her old traditions, Japan has merely pretended to throw them aside. Her Parliamentary Constitution is only a stucco façade, behind which works the efficient and well-directed machinery of an ancient military oligarchy. The great fighting clans survive, but under the menace of foreign aggression have united on a national aim instead of warring for clan supremacy.

The case of the people of the United States is even more instructive, for it was they who set the fashion of paper Constitutions. They were a powerful branch of a highly advanced nation; and when they broke away from the Mother-State they altered little or nothing of their traditions. As is well known, they modelled the office of their President exactly on that of the British monarch of the time; and all that their paper Constitution really did was to embody matters of actual practice into a set of rules which now seriously interfere with the natural and necessary evolution of the forms of government. Instead of the institutions of the American people being more progressive than those of the Mother-State, they are more backward. The paper Constitution has been a hindrance to the free growth and adaptation of forms of

government; and lawlessness has increased, because the laws have not developed with the change of social and economic conditions. Many of the political abuses of the United States are due to the fact that a keen commercial and industrial people, absorbing every year a vast multitude of immigrants of a rather low type, are still living under a Constitution framed by a race of hardy, simple farmers of the eighteenth-century school.

The Failure of States Manufactured on Lines Laid Down by Political Philosophers

Practically all the States manufactured under the inspiration of Locke and Rousseau, Tom Paine and Bentham, have completely failed. The races composing these States have either developed a military despotism, as in Mexico, where free institutions are only a mask; or the money-power has become the organising force, and created a practical oligarchy, as in Chile. Instead of Parliamentary elections being decided by ballot, they are fought out with rifles, votes only counting when the party in power can count them, and overlook all those given by its opponents. The system was rather anarchical in its beginnings, and so it still continues in Hayti; but where European and Northern American capitalists have an acquired stake in the country, the government is settled by a native despot or group of oligarchs, well supplied with the funds necessary in maintaining order. As a rule the rights of man which are carefully set out in the paper Constitution are but little regarded; and where the native working population did not originally possess something like a real equality before the law, it has very rarely attained that equality at the present day. The fact is that a society cannot be made; it can only grow. And it grows by developing its own culture, or by assimilating the elements of progress in surrounding nations.

The Curious Succession of Book-Made Theories Divorced from Active Life

In other words, a society is an organism. It was left to Herbert Spencer to discover this all-important fact, and to prove it in his "Principles of Sociology," the first volume of which was published in 1876. This work produced a revolution of thought comparable to that effected by Darwin's "Origin of Species." It overturned all the ideas on which States were still being manufactured in the Old World and the New, and it gave an entirely new direction to the course of social and political studies.

Until Spencer began to study human societies from the evolutionary point of view, there was a curious and impressive agreement between the earliest myths and the latest theories of the origin of the laws and constitutions. Lycurgus of Sparta and Solon of Athens had, so traditions went, manufactured States in the manner of Jeremy Bentham. They had studied the laws and customs of the most advanced nations of their age, and had then drawn up an artificial Constitution which they imposed on the people, with the result that a higher state of civilisation was immediately created. Such were the myths of the Greeks; and almost every ancient race traced its social laws in a similarly mythical way to some wonderful legislator.

So, when Plato tried to reform his country, he adopted a method of Lycurgus, and worked out the idea of a philosophic republic. At the revival of learning, Sir Thomas More framed his "Utopia" on the Platonic model, and lately Mr. H. G. Wells, and a score of other writers, have provided us with new versions of the "Utopia."

Spencer's Suggestion that Society is an Organism Developing Like Plant Life

Nearly all political thinkers before Spencer followed this line of thought. While making less demands on the average man than the Utopians, they tried to provide new nations with Constitutions embodying the best experience of the most advanced political communities. And every historian helped to develop the old myths and the new theories, by enlarging upon the doings of kings and statesmen, who, at best, only interpreted the social and economic forces of a people.

All this was shattered by Herbert Spencer, on approaching the matter from the evolutionary point of view. Spencer began by comparing society to a living thing, which grows from a simple cell. As it grows, its parts become unlike, and it shows an increase of structure. Moreover, the unlike parts at once assume activities of unlike kinds. These activities are not merely different, but their differences are so related as to make one another possible. All the parts are mutually dependent, living by and for one another. In short, a society is developed on the same general principle as a plant or an animal. It is an organism of a special kind—a super-organism.

The point will come clearer, perhaps, if we put it in a reverse way. Every living thing of appreciable size is a society. In one low form of life the cells at first move about separately, and feed and grow and

multiply, and then at last melt together in a mass, sometimes barely visible, and sometimes as big as a man's hand. It can be seen, a gelatinous body, slowly creeping over decaying matter and even climbing up the stems of plants. It belongs to the order *Myxomycetes*. In other cases, instead of living units which are originally separate and lose their individuality by massing together, we have units which arise from multiplication of the same cell, and do not part company, and yet very clearly display their separate lives.

The Sponge as an Instance of a Social Aggregation from Individual Lives

The fibres of a sponge are clothed with a gelatinous substance, which is composed of small living units. We cannot deny life to the sponge as a whole, for it shows corporate actions. The outward units partially lose their individuality, and are fused into a protective skin; the supporting fibres are produced by the joint agency of other small living units; and it is also by their joint agency that currents of water are drawn into the sponge and then sent out. Thus the sponge has a feeble life as a whole, yet the lives of the myriads of tiny living units are very little subordinated. They form, as it were, a primitive society, with scarcely any subdivisions of labour and service. The sponge, in the words of Huxley, represents a kind of submarine city, where the people are arranged about the streets and roads in such a manner that each can easily seize his food from the water as it passes along.

Even in the highest animals this relation between the life of the whole and the lives of its separate parts is still discernible. The mucous surfaces, for instance, of the air passages are covered with minute cells packed side by side, each cell bearing on its exposed end several hairlike, vibrating organs. These organs are continually in motion, and they are essentially like the organs of the minute forms of life which live in the passages running through a sponge.

Separate Yet Corporate Life Visible in the Organisms of our Own Bodies

Just as the joint action of the hairy sponge units propels the current of water, so the joint action of the ciliated cells of our bodies moves forward the secretion that covers them. If there needs further proof that these mucous cells have independent lives, we find it in the fact that when one of them is detached and placed in a proper liquid it moves about with considerable rapidity by means of its vibrating organs. Seeing, thus, that an ordinary living organism may be regarded as a nation of units which live their own lives and sometimes have a considerable degree of independence, we shall have little difficulty in regarding a nation of human beings as a special kind of organism.

In every organism, the minute living elements grow and play their parts, and then decay and give place to new elements, while the animal as a whole tranquilly continues its life. Cells are formed in the deep layer of the skin; and as they enlarge they are thrust outward and flattened into the outer skin, where they come off in scales, while younger cells beneath take their places. In the same way the cells of the blood feed and grow and die, and are replaced by another generation of living units. All this replacement, rapid in some tissues and slow in others, goes on at such a rate that, during the life of the entire body, almost each portion of it has been produced and destroyed.

Society Lives and Grows as a Whole While its Component Institutions Decay

We can all see the same process going on in the organism of a society. The small living units are continually dying, and giving place to a younger growth. Governing bodies, religious corporations, armies, and institutions of all orders show us a continuity of life much exceeding that of the persons constituting them. And, as part of the same law, we see that the existence of the society at large endures longer than that of many of its less important structures. Private unions, local public bodies, and towns carrying on special industries, and even many secondary national institutions, may decay, while the nation goes on developing in size and organisation. Hence there arises in the social organism, as in the body of an animal, a life of the whole quite unlike the lives of the units, though it is produced and maintained by them.

Of course, every thinking man for thousands of years has seen that there was something special in human societies. Even those persons who fancied that nations had been suddenly manufactured by some legislator of genius recognised that there was something in the whole which did not reside in all the separate parts. It was clear there was some kind of organisation, but it was generally thought that this organisation was like that of a machine. Primitive groups had been welded together by new customs, new laws and new conventions, and transformed into a more powerful piece of social machinery.

THE CROWNING MOMENT OF MAN'S LATEST TRIUMPH IN LEGISLATIVE ORGANISATION

THE DUKE OF CONNAUGHT CONSUMMATING THE PACIFICATION OF BRITISH SOUTH AFRICA BY OPENING THE NEW FEDERAL PARLIAMENT

When this view is reduced to practice, it results in swift revolutions conducted by force. Religious reformers, on the other hand, have often had an insight into the truth of the matter. They felt that a community was something more than a political machine; and in ages of unrest they went straight to the source of social life, and tried to raise, inspire, and enlarge the social conscience.

Here we arrive at the point of fundamental importance between the old view of society and the new. A thing that is manufactured can be altered from the outside, new parts being abruptly substituted for old parts. In an organic being, however, the change must take place from within. A new part cannot suddenly be inserted; it must grow from within outwards. From the moment of its birth to the moment of its fullest development, it must be vitally connected with the whole of the living structure of which it is an element. What is called a revolution in regard to human societies is never anything more than a kind of surgical operation, in which some part that is thought to have become useless and unhealthy is severed from the main living body. But growth, reproduction, and decay—not surgical operations—are the normal life-processes of living bodies and social bodies.

The Early Growth of Society by Fission Like the Similar Growth of Vegetable Cells

A nation grows by developing its structure. Its population splits up into complex groups, with different but connected activities, just as the cells of an animal's body separate into different organs, and carry on an increasing division of labour. The lowest forms of life multiply simply by fission. Having grown to their full size, they divide into two parts, and each part drifts away and begins life on its own account. So it is with the lowest form of society. A small group of families, without any chief, grows at last too large to maintain itself on its special hunting-ground. It is compelled to divide into two groups, one of which moves away in search of a more abundant food-supply. It is very probable that in this manner the earliest colonising race of mankind gradually spread over the earth. There are still a few spots where savage races remain at this low stage of social growth.

The next stage in the evolution of life is seen in the minute vegetable-cells which cluster together in shapeless masses and small threads, discs, and globes. They form a plant without root, stem, or leaves. Becoming more organised, they develop into a permanent structure, and put forth a leafy shoot. From this shoot branches come, and the branches develop new branchings. This compounding and re-compounding of cells can also be traced in the animal kingdom. A similar process goes on in the evolution of societies. Mere increase in number in a primitive group does not result in or have any inherent relation to a higher type of organisation.

Social Division Followed by Cohesion Brought About at First by War

Social advance is only obtained by joining family communities into tribes, without doing away with the old clan and family divisions. This development may be seen now going on among uncivilised races, as it once went on among the ancestors of modern peoples. Instead of a number of small and independent groups, such as the lowest savages show us, more advanced tribes display a certain cohesion. At first the new and larger combination is not permanent. A common form of the process is that described by Mason, as occurring among the Karens of Burma: "Each village, with its scant domain, is an independent State, and every chief a prince; but now and then a little Napoleon arises who builds up an empire. The dynasty, however, lasts only with the controlling mind." And Livingstone said that the same thing was constantly going on in Central Africa in his day. The newly made nations, however, were like plants of the lowest kind, in which the union of the cells was only temporary. Tribes and clans fell apart on the death of the man who had welded them together by the sword. There was no inner principle of union among them.

The Natural Trend of War into Military Dictatorship and Despotism

The best results were sometimes achieved by a primitive system of feudalism, by means of which the heads of each tribe were allowed to retain considerable authority, and met in council under an overlord. Here, a common greed for the spoils of war, and a common fear of defeat and disaster, served to keep alive the principle of union. Single outbursts of tribal jealousy and tribal ambition were quelled by the overlord, who could use the power of all the faithful tribes to repress any partial rebellion or secession. This form of compound grouping is found at the present day in Afghanistan. Indeed, the social progress effected by warlike federations of tribes can be traced in the history of many civilised nations.

As a rule, it made for despotism, for the

overlord usually succeeded, by reason of the poor organisation of each tribe, in getting into his hands all the military power. This was especially the case in the large and fertile regions, in which were founded the first civilisations. Each small and newly formed principality soon found itself opposed by similar warlike combinations of tribes. In the ensuing struggle, each overlord became a military dictator. On the field of battle he had to be obeyed instantly and without question. So when the last battle was won he put to political uses all the forces of military discipline, and became a despot, like the Pharaohs of Egypt and the kings of Mesopotamia.

Military Discipline the Bond Most Suited for the Mind of Undeveloped Man

What human societies needed first and most was a solid backbone of laws clearly laid down and rigorously administered—a backbone running through all divisions of clan and tribe, varying religious practices, idolatries, and superstitious customs. A great ennobling religious movement would have been a consolidating force; and so would have been the spread of a fine common source of culture, such as is found in the methods and results of modern science. But the mind of man was not ripe for a religion of the divine brotherhood of men; and the science of even the agricultural States was small in quantity and poor in quality, and overlaid with primitive magic. Commerce was often but a rude kind of barter in the absence of an international currency. So the early stages in the development of the social organism are found in military organisations with a despotic tendency. Thus we get the military type of society, in which social co-operation is compelled by force. When, however, a nation has been hammered into a permanent society and attached to a fertile soil, it begins to develop in another direction. Here is the origin of the industrial type of nation, in which the co-operation is voluntary.

A New Cement Brought to Society by Industrial Co-operation, with New Grouping of Interests

Not only does the nation become larger in size than a low-type society, but it quickly grows more solid in texture. The original family group increases in number more quickly, and, continuing to split up into new families, it fills out all the national territory. This growth of population leads in favourable circumstances to new social developments. In civilised States there is produced a new complexity of organisation. The community becomes at once more united and more divided. That is to say, the various classes branch out into numerous different pursuits; and yet, during this continual division of labour, the dependence of unit on unit and of group on group is intensified. For instance, a primitive blacksmith discovers his own iron ore, and takes it to his house, and there smelts it, and at last makes implements from it. Now, however, owing to the evolution of society, this single industry has been split up into a marvellous diversity of employments.

The evolution of the industrial structures of the social organism is as important as the development of its political organisation, the growth of industries being, indeed, vitally connected with the civilisation of mankind. It made for the control over natural resources, on which still depends much of the welfare of the human race, and it promoted co-operation of the best kind. The primitive form of an industrial structure of society is strikingly similar to the primitive form of some of the large organs of an animal body. In animals of a low type, there is no liver, and the secretion is performed by a number of uncombined and separate cells. So among the lower savages each worker carries on his occupation alone, and disposes of the product to consumers.

Industrial Evolution and its Organisation into Castes and Guilds

In certain negro villages, for instance, the most ingenious man is usually blacksmith, carpenter, architect, and weaver all in one. In ordinary circumstances, this solitary Jack-of-all-trades, who, by his skill, has distinguished himself from his fellows, can only bring up one of his sons in his calling. There is no room in the simple community for two or three craftsmen. If, however, the social group develops without splitting up in search of food, all the sons of the Jack-of-all-trades can help their father in his work, and continue his occupations when he is gone. Let us suppose that the village is able to grow because more attention is being given to agriculture. In course of time, with gradual improvements in methods, all the fertile land for many miles around becomes covered with a farming population, and a town springs up. By this time the family of the solitary craftsmen will have grown into a clan or caste of artisans. Eventually it becomes an imperative custom that each man shall bring up his boys to his own particular trade.

This stage of industrial evolution was reached by many famous nations. A division of castes; based on occupations,

obtained in Egypt, Hindostan, Peru, and Mexico. By the Theodosian code, a Roman lad was compelled to follow the employment of his father. In mediæval France handicrafts were inherited, as they were also in England. From the family connections of the various craftsmen there was evolved the guild; and it very often happened that families engaged in the same industry formed a cluster in some special part of the town.

There is no sudden leap from the household type to the factory type of industrial structure, but only a gradual transition. First came the old trade guilds, in which members of the family received an apprentice, who became practically an adopted son. When this modification was established, there followed, with the continued development of trade, the introduction of apprentices, who merely became journeymen. The master grew into a seller of goods made by the journeymen; and as his business enlarged, he ceased to be a worker, and became a distributor. This led the way to establishments in which the journeymen far out-numbered the working members of the family. And at last, with the use of mechanical power, there came the factory, and the factory grew into the factory town.

In all this we have a striking example of the organic growth of an important social structure. Nobody designed it; nobody directed its development. It was a gradual evolution, unnoticed even by modern legislators until some of the factory owners were so misusing their power over the workpeople as to produce national disorder and national disease. To check them, it was necessary, among other things, to revive the old guild system in the modern form of trade unions. At the present day there seems to be some danger of certain important parts of the industrial structure of society breaking down, and nationalisation is often put forward as the only permanent remedy. Herbert Spencer always held, however, that this remedy was worse than the disease. In his view it meant interference with the process of organic growth: an industrial peace making for the happiness of one generation of workers, but conflicting with the future interests of a society as a whole.

A TRANSITION STAGE IN TRADING—AN APPRENTICE IN THE TIME OF CHARLES I.

ON THE THRESHOLD OF DESTINY—THE DAWN OF WOMANHOOD

"STANDING, WITH RELUCTANT FEET, WHERE THE BROOK AND RIVER MEET, WOMANHOOD AND CHILDHOOD FLEET"

From the painting entitled "The Dawn of Womanhood," by Mr. T. C. Gotch.

LIFE'S SECOND START

The Supreme Importance of the Dawn of Adult Life with its Susceptibility to Splendid Inspirations

A STUDY OF SOULS IN THE MAKING

OUR consecutive study of the demands of nurture in national eugenics now reaches a period which stands more completely apart than any that have preceded or will follow it. Even birth, with all its risks and needs, is only a change of environment, after all; adolescence is more, for it is a "change of heart," a change within the very deepest substance of the individual mind and body.

We have traced the needs and conditions of the new life from its beginning, which involved us in the problem of expectant motherhood, up to what is at present the approximate end of the "school age" in this country. Without admitting for a moment that this should be the end of all real and responsible care of the young life, we may yet admit that there is something natural in the change at the age of fourteen or so. For this represents the period of puberty, the beginning of adolescence, when everything matters and matters for ever.

Adolescence literally means *becoming adult*, and we are to look upon this period as a new birth—nay, more, a new begetting, the begetting and birth of the adult. Our business in the present chapter, for theory and practice, is clearly threefold. We must study the facts of adolescence; we must survey the history of man's treatment of this problem which the next generation ever throughout the ages offers afresh to the present generation; and we must lay down the principles of action which the eugenic ideal demands, and which may be justly based upon our physiological and our sociological inquiries.

That, we may observe, is the rational method of our science. Its object is the making of certain kinds of individuals—then we must understand the individual, which is physiology; but this has to be done in and under the conditions of human society—then we must study society, which is sociology; and, lastly, the practical Eugenist frames his policy accordingly. First, then, for our physiology.

Adolescence is not a sudden event, though at times its results may appear suddenly and stagger us. We may not unfairly describe it as a matter of a decade, say, from the fifteenth to the twenty-fifth year or so. Yet again, we must repeat that individuals vary, and that this is only a general statement, around which our ideas may be arranged—that adolescence, or the making of the adult, begins (with comparative abruptness) at puberty, say, in the fifteenth year, and ends (very gradually) a decade later, when the individual is now personally mature.

No sooner has the writer set this down than he longs for pages in which to qualify and modify it, so little justice can any such statement do to the multiform facts of man. For instance, let it never be said that no man grows after twenty-five, nor yet that many a youth of fifteen or eighteen may not already be far higher in human *status* than he will ever be again, alas!

Yet, further, we must realise that, though the biologist may call an organism mature when it can reproduce itself, man transcends all lower reckonings, and though the advent of puberty means the possibility of reproduction, yet man is man, with a personal and individual development such as no animal can compare with, and he needs another decade, say, before his own development becomes more or less complete.

How different from the innumerable instances of other forms of life, especially male life, which develop, perhaps for long periods, until they become capable of reproduction—the sole purpose for which they were made—and then die in a few hours. During the course of adolescence, bodily

and mental changes are in more or less steady progress, with consequences many of which amaze us afresh in each new case, however familiar we may be with them. These are, of course, internally developed changes, and in no sense the product of nurture. Yet nurture, of course, can affect them, for good or for evil, within limits.

The writer is inclined to believe two propositions which may seem almost incompatible, yet which experience seems to justify: first, that the importance of our care and conduct, our nurture, of adolescence is very great, entailing the utmost responsibility; and second, that most students of this subject have probably much underrated the obstinate forces of "nature," which will very largely make and mould the new individual as they will, our best constructive efforts notwithstanding.

The upshot of these two assertions, taken together, may be that our duty, above all, is to *protect*, to ward off the special dangers of this period until, happily, the new young character can protect itself. Even though our share in this has been less constructive than we suppose, how well worth the doing.

The Discovery of Adolescence an Epoch-Making Achievement of the Twentieth Century

All individuals are naturally different, and no two individuals have exactly the same environment—air and light, perhaps, but not companionship and books. Evidently, to understand the laws of adolescence, and to decide what will be the best conditions for any particular individual, is a task very nearly beyond human wisdom. The beginning of it must lie in a wide, systematic, cautious, and, above all, sympathetic study of the subject, and that study, always needed, and by no means dependent altogether upon the resources of modern science, was actually never made until the present century.

This is one of the strange facts which the history of human thought is crowded with. But there it is; and though many may think that radium, and "606," and the mosquito theory of malaria, and the corpuscular theory of matter, and the rediscovery of ancient Crete are the great scientific events which remove us from the nineteenth century, those who know that "the proper study of mankind is man" would certainly put down the discovery and the promised recovery of adolescence as one of those truly epoch-making achievements, which make even the nineteenth century seem remote. It has had no headlines, even in the best papers, but it has many in the best heads.

The man who gathered together and co-ordinated, and greatly added to, the knowledge then available was Dr. Stanley Hall, President of Clark University in the United States of America. His two large volumes, entitled "Adolescence," now the classic of our subject, were published in 1904, and have since been discussed, and have led to new observation and discovery, in every part of the civilised world. To the follower of Stanley Hall, every young person is a mystery, a miracle, a scientific phenomenon, a specimen, a tragedy, a proof of "fatalism," a proof of "freedom," a portent, a menace, and a promise—all these incompatible things and many more. This study has opened a new world for our observation, our admiration, and our control.

An American Book that is a Study of Souls in the Making

Readers who wish to look more closely at it than is at all possible here, should consult the small and inexpensive volume, "Youth: its Education, Regimen, and Hygiene" (Appleton, 1907), in which Dr. Stanley Hall has epitomised his treatise, omitting most of the scientific evidence and examples, but retaining the conclusions and adding some new matter on moral and religious training which is of the highest value. Our business here is the survey of adolescence for the practical eugenic end of determining national duty in the matter, but the reader who follows the advice here given will see that this is a field of scientific study which rivals anything in field botany, or natural history, or the study of stars and their making. For this is, indeed, none other than the study of souls in the making, and "what know we greater than the soul?"

The Time when the Powers of Life Mysteriously Generate New Funds of Energy

Fundamentally, of course, adolescence is preparation for parenthood, and if we regard it as such, and urge the importance of eugenic education or education for parenthood, to which our next chapter will be devoted, there is clear physiological warrant for our argument. But here we are concerned with the welfare of the individual adolescent, and the internal developments, associated with physiological preparation for parenthood, must be understood in the first place. They depend upon a change in the chemistry of the body, a change initiated by—or for, we cannot say which—the "germ-plasm" or racial tissue.

These changes involve the production of what are nowadays called "internal secretions"—invaluable and potent substances,

as yet little understood, which are produced by certain glands of the body, not as, say, the saliva, the perspiration, the bile are produced, for departure from the body, but for internal purposes, in order to modify the development and behaviour of some other part of the body than that in which the particular secretion is produced. It is these internal secretions that act mysteriously upon cells in the larynx, which have lain there inactive for years, so that it enlarges, and the boy's voice "breaks;" cells in the skin of his chin, which have similarly lain inactive since their first formation, but which now begin to produce hair; cells in all manner of glands and tissues, whereby the form of boy and girl, hitherto so largely similar, are modified and developed, in general and in detail, each along their own lines.

These illustrations, each of which is a problem for future science to unravel, are mere crudities compared with those which may be found in the nervous system and in the *psyche* of the boy or girl. Profound and subtle changes now occur, dependent upon the inflowing or the uprising of an immense new fund of energy, mysteriously generated by the powers of life at this time.

The Sacred Dawning in every Young Life of Glorious Possibilities

In the higher races, and above all in the highest members of the highest races, this fund of energy is used and blessed in a fashion to which nothing else in the world of life bears any parallel. All possibilities are open, from that of a cataract in flood, working destruction, uncontrollable save from without by rigid force, and even then liable to break its bounds and work havoc, to the beautiful contrast of a stream which flows, by many gentle channels, each a centre of growth and beauty and power, until at the end of the years the river of life returns to the great deep, with a noble record and a fertile delta behind it.

All possibilities, we have said, are open. But if we take cases from either limit, we shall see at once that we were just in describing adolescence as both a menace and a promise. The Eugenist, seeking the best nurture for this unique period of life, must too often watch and hope, while the inner forces, determined not by anything he can do, not by any nurture, but by "nature" or heredity, carve for themselves what channels they will.

He will learn that adolescence often definitely means degeneration, as a rule much more marked in man than in woman. The child is nearer the ideal of the race. Whatever the explanation may be, there is the sober fact; our best twentieth century science, without any religious or historical bias, reports that by some means men must contrive to become more like little children, for of such is the kingdom of the future—the future kingdom of heaven and earth. The great and good man whom eugenics desires is a glorified child.

For many men, even of our own race, and nearly all men of lower races, are lower in the scale of life than they were as children. There is no question as to their physical degeneracy. The hair on the boy's chin, of which he is so proud, is palpably a reversion. The air spaces above his eyes are another. The lowered type of voice is a third, and so on. This degeneracy does not seem to occur in woman, at any rate in appreciable degree.

The Terrible Alternative that Adolescence may be a Start towards Degeneration

At first reading or hearing, this theory of degeneration at adolescence seems utterly irrational and improbable. But the records of life are full of the same thing. The barnacle is only one of countless types which are free, promising, original, self-supporting even, in immaturity, but which degenerate when they grow up, becoming fixed, unprogressive, often parasitic, and evidently nearer lower forms of life. The problem for man, who cannot prevent the physical changes that unmistakably carry him nearer to the ape, is to turn some part, at any rate, of the new forces to the really onward development of his brain and mind. The fight will always be a hard one, and can never, perhaps, be completely successful. Even Thomas Hood, a true poet as well as a punster, lamented that he was farther off from Heaven than when he was a boy. Henry Vaughan, also, and Wordsworth, in his greatest ode, have taught the same lesson—which is the newest scientific discovery regarding man. We must accept the fact, and we must endeavour to control it, if possible.

The Birth-time of the Adult the Supreme Opportunity for True Education

It may often be possible—if only we will try to understand the psychology of adolescence. This is, above all, the real period for education, or leading forth, since there is so much of new now to lead forth, and since it is in such notable degree amenable. There is an extraordinary blossoming of the intelligence in higher types, to name nothing else. But we must

name everything else—emotions and will, character and self-control; all these are *born*, in a profoundly true sense, at adolescence—which is the birth of the adult.

Their modifiability is remarkable, even though nothing will extirpate the essential differences between any two individuals. The forces of suggestion, imitation, and sympathy, that most potent trio, so rarely recognised, have a magic at this age which they never had before, and will never have again. This is, therefore, the period of character formation, which every educator worth a straw since time began for man at all has declared to be the supreme aim of education; for without character who is prepared for complete living?

The Supreme Crisis of Life when Personality is being Shaped and Inspired

Everything that we have already laid down as regards the personality of the teacher holds good now a thousand fold. The child is becoming, or may and should become, a new and higher personality; it may become a lower kind of personality, far less worthy of the name. What personalities is it to be now brought in contact with? What people, what books? Who are to answer its questions about the meaning of life? Whose example is it daily to witness; to witness and, perchance or perforce, to follow? What habits of body and habits of mind is it now to form? These habits of body and of thought and of aspiration are the channels, in our image of the river, wherethrough the life is to flow to the beyond. And now is the appointed time.

It is largely now or never. In middle age and old age one may recapture the joy of youth; the child and the poet need not quite die in any of us, so long as we can breathe at all. But the opportunities, the peril, and the promise of adolescence can never be rehearsed. You pass or you fail at this examination; but you may not enter a second time. There is nothing else like it in life.

The Teaching of the Child to Know What is Worth While and What is Not

The soul of the child may now march on, and reach to "the immensities and the infinities and the eternal verities," as the great writer of our fathers' adolescence used to say. Or it may turn to others who also write for youth, the poisoners of young life, who seek to turn into the one gorge of sex all those forces for which the seeds of the wide plain are waiting, perhaps waiting in vain.

This is what the tutor of adolescence should know. The tutor is literally the saviour, he who makes and keeps safe; a very just conception, from our modern standpoint. He is to protect the child from himself or herself, by directing the new forces into channels which are safe and fertile. He must teach the child to know what is worth while and what is not. That is the only real wisdom, which is "the principal thing." Wisdom is to know trash for trash and treasure for treasure, to scorn the one and seek the other. That is the business of the educator or the tutor—to promote the great choice and make impossible what Dante called the "great refusal."

The Eugenist cannot pretend that anything in the past records of man entirely realises the demands which he now makes for the nurture of adolescence; if only for the reason that his concern with this period of life is a double one, since he desires the best for the individual, and also desires that individual to become the best possible parent. Yet nothing can be clearer than the sociological or historical record in showing that, in various degrees and for various ends, wise or efficient nations and races have always appreciated the unique importance of adolescence, and have endeavoured to utilise it. This is a large subject, fit for volumes of comparative anthropological and historical research. Here we briefly note the outlines of the evidence.

How Adolescence Impressed Savage Races and the Nations of Antiquity

Observers report that many primitive races of the present time have their special ceremonies for adolescence. Their function is partly mystic, partly religious, partly practical. The young people are taught certain facts of adult life—often, no doubt, coarsely and savagely—they are initiated into adulthood, and they are required to make certain undertakings for the future. The details vary widely in different instances, and for the two sexes, but the broad outlines are the same. Not that such ceremonies necessarily retain much, if any, of their ancient significance. Whatever is set and appointed is apt to degenerate—the letter, which is tough, strangles the spirit, which is tender. The comments of cynicism may begin at home. But it seems clear that many ceremonies, which missionaries and the earlier anthropologists have misunderstood, or thought to be nothing but orgies of debauchery, were originally none other than solemn and formal initiations into the duties and responsibilities of adult life.

Similarly, also, if we go back into history,

we find that the beginning of adolescence has been recognised and employed for the patriotic and national purpose, especially as regards boys. Thus, in Rome, we find that the boy, in completing his sixteenth, afterwards his fifteenth, year, substituted for the boy's toga, or cloak, which he had hitherto worn, the *toga virilis*, the Roman national dress, which was allowed to be worn by free citizens only, and which constituted the boy a responsible citizen of the greatest empire in the world.

Attempts to Influence the Young Life Opening to the Infinite Within and Without

With this there went such ceremonies and injunctions and solemnities as should deeply impress the boy's heart at this most impressionable or suggestible age, and make him worthy of his State, a youth strong and brave, fit to be free, because controlled from within. We may compare such a practice as this of Rome with our own care of boys at the end of their fifteenth year, and for some time before and after. But to that we shall at last be compelled to come.

The Roman example is illustrious, and doubly significant for the citizens of the greatest Empire of later days. It may suffice for this aspect of history. But a word must be added regarding the appreciation of adolescence by the forces of ecclesiasticism and also by those of religion. This, we may remember, is the age of marked piety, the age of religious experiences, and the age of "conversion." The young life opens to the infinite, the infinite within as well as the infinite without.

There is a saying, attributed to the Jesuits, that if you have your way with a child during its first seven years, you need not trouble about the rest—it is always yours. If this statement be indeed of Jesuit origin, it does little credit to the supposed acuteness of that Order. For it is palpably untrue. But if any such statement may be made of any period of life, it may be made of adolescence, when pre-eminently the possibilities of the religious life unfold, and when the personal influence of the teacher, or of the Teacher, finds the soil prepared for it.

How all the Wisdom of the World Concentrates its Efforts on Budding Youth

Hence we need not be surprised to find that, all over the world and in all times, the forces of ecclesiasticism and of religion have made special efforts to renew their hold upon the new beings who come forth at adolescence.

Since the most effective illustration is usually that which is drawn from nearest home, we need only point to the rite of Confirmation in the Church of England, with its Catechism and its systematic preparation. The psychologist and the Eugenist, putting on one side for the moment their own beliefs in these matters, cannot but be impressed at such evidence; and the Eugenist, who seeks not merely to know but also to do, may well hope that, unless the past exhausted the possibilities of wisdom, the future may witness a fruitful extension of the principles which the practice of the Church illustrates so notably to-day.

We have drawn illustrations from the sphere of the State, from the sphere of the Church, and now we turn to the sphere of work. Again we find that successful and efficient nations and industries have recognised the importance of adolescence, and have turned its special opportunities to their purposes. Now is the time for the child to learn. Now is the time for him to form habits of the senses and of the muscles. Now is the time to arouse in him the sentiment of *esprit de corps*, to attach him to some trade, some guild, some profession, some interest in the State, which shall be his henceforth, and round which his young and growing personality shall twine.

The Decisive Opportunity for Fixing on Ideals and Learning Control from Within

Not least of all, now is the time to learn those difficult but priceless habits of application and discipline, and to decide, once and for all, that of the two classes of people, those who stick to it and those who do not, the youth shall belong to class number one. Now, also, the habit of learning may itself be learnt, perhaps—it is not for all, be they tutored never so wisely—with all that it means for the indefinite, nay, the infinite continuance of growth and development, and as a life-long preventive against the risk of degeneration.

There are finer and more valuable habits still. Now is the time when concerted games begin to appeal to the fortunate youth. He has the great chance of learning to play not for himself, but for his side, the habit which makes the champions of mankind what they are. They play for their side, and their side is Man. Youth may learn to play the game, and to scorn what is "not cricket," or, as the Japanese say in their crude way, "not poetry." This means discipline, among other things, and leads us to the highest possibility of this age, the most richly crowned with reward for success, the most appallingly cursed with penalty for failure. Is this youth, or this maiden, to be controlled thereafter from within or from

without? Control there must be, of course, in any form of human society. But the question is, what kind of control? There is a great community of various animals in Regent's Park, peaceful and stable. The carnivors do not kill the herbivors, the lion and the lamb lie down together. But there are bars between them. The control is from without. If we are to have a society of human beings, in which all types, not actually anti-social, may flourish, and to which all may contribute their peculiar quality and capacity, a society which is not only stable in the present but dynamic towards the future, its control must be not that of the menagerie, but that of man and man alone, control from within.

Above all, then, adolescence is the period when youth must learn self-control. Never was this argument more necessary than to-day, when the whole theory of control and responsibility and keeping your word, and not being hustled along by the crowd, seems to be imperilled by modern forces and tendencies. And it is at this point that the Eugenist reiterates his long-held conviction that the nation must discover and recover its adolescence if progress is to be obtained, or if even the fruits of the past are to be maintained.

The Need for a National Recognition of the Demands of this Vital Problem

That is our duty, and if at times the Eugenist is inclined to despair, there are at least three signs of promise of which he may remind himself and take heart of grace.

First, the cry against the present neglect of adolescence, the decay of apprenticeship, the making of "hooligans," and the wicked folly of "blind alley" occupations for young adolescents, considered from the national point of view—all this is beginning to be heard. It will not be permitted to die down. Legislative tendencies show the course of public opinion. The raising of the school age will come before very long—perhaps even before any radical reconstruction of our educational theory and practice. The "half-time" system is to cease for ever. We know it is for ever, because in the international struggles of the future there will be no room at all for any people that practises such local suicide on any scale at all. Though no one in political life south of the Tweed dare openly and primarily advocate the raising of the school age, Scotland is already beginning, by her system of compulsory continuation schools, to recover her adolescence. England will follow suit, in self-defence.

So much under that head. Secondly, we may note, quite briefly, the marked decline of drinking among youths and young men. Beer is still offered to the boys at night in our most expensive public schools, though it would be hard to find a more flagrant instance of defiance of all rational principles in the care of adolescence, and though the custom has been roundly and scathingly condemned by Dr. Clement Dukes, formerly physician to Rugby School, who is our first authority on "Health at School," to quote the title of his authoritative book. But the boys themselves are refusing the beer, being wiser than their tutors in this respect, and are thus declining to handicap themselves in the ever-pressing problem of self-control at their age and in their circumstances.

The Boy Scout Movement a Hopeful Sign of the Times

Lastly, the Eugenist cannot but look with delight at the Boy Scout movement, which is as much a product of our century as any other of its boasted achievements, and, perhaps, the best of them all. It may be clearly demonstrable that militarism leading to war is anti-eugenic, causing a "reversed selection" by its destruction of physical fitness. The Eugenist is, nevertheless, compelled to judge the Boy Scout movement as it stands, and by its present consequences. His business is to decide whether the principles of education, personal and social, as there illustrated, consort with his knowledge of the psychology of childhood, and, above all, of adolescence.

The writer has it on evidence he can implicitly trust that the principles of this movement exactly conform to what a laborious science, or the happy instinct of the man who understands and loves boys, would indicate as trustworthy and fundamental.

The Need for a New Science and New Art Creative of Sound Boy Life

A thing like this, so profoundly rooted in the nature of childhood and adolescence, so palpably adjusted to the weakest and most vital spot in our present nurture of the next generation, has come to stay, and to grow and to conquer. Strange that, even in the first decade of our century, "the tongue that Shakespeare spake" should have given to the world, by the mouths of Dr. Stanley Hall and Sir Robert Baden-Powell, the theory and the practice of a new science and a new art, which may yet be found more truly vital, more creative of life present and life to come, than anything in the records of merely physical science in the nineteenth century.